ENERGY CONVERSION

LITERATURE ABSTRACTS

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CONTENTS

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I. ENERGY CONVERSION
A. General Information

2826
AID FOR ELECTRONICS. Chem. Wk. 92:50, Apr. 7, 1962.

Several developments of interest are mentioned, e.g. RCA showed, at the IRE convention, an experimental generator using thermocouples made with newly developed germanium-silicon alloy. RCA also displayed a trio of ceramic-metal thermionic energy converters that are said to provide high-power density at relatively low temperatures.

The Thermo-Electron Engineering Corporation has developed a 30-watt cesium vapor thermionic converter that operates at 1500 C.

Bell Telephone Laboratories announced at the American Physical Society, that it had achieved the highest figure of merit ever measured (8.6z 10^{-3}/ degree Kelvin) by placing a bismuth-antimony alloy in a magnetic field of 1,000 gauss at -173C.

2827
Auger, Pierre. CURRENT TRENDS IN SCIENTIFIC RESEARCH. SURVEY OF THE MAIN TRENDS OF INQUIRY IN THE FIELD OF THE NATURAL SCIENCES, THE DISSEMINATION OF SCIENTIFIC KNOWLEDGE AND THE APPLICATION OF SUCH KNOWLEDGE FOR PEACEFUL ENDS. 245p., New York, United Nations, 1961.

In ch. V entitled Fuel and Power Research, nuclear and solar energy are discussed, in general.

2828
Bendersky, Joseph. ACCESSORY POWER UNITS - PRESENT AND FUTURE. Hydraulics and Pneumatics 14:94-95, Dec. 1961.

Methods are discussed for providing auxiliary power in space vehicles, and areas in which further development is necesary if future APU requirements are to be met. (Internatl. Aerospace Abs. 2: 62-2901, Mar. 1962)

2829
Bruni, M. ELECTRICAL GENERATORS OF THE FUTURE. Elettrotec. 48:367-380, June 1961.

In Italian. A comprehensive review of advanced schemes of power generation includes a description of the fuel cell, thermionic, thermoelectric and magneto-hydrodynamic generators. In each case a description is given of possible practical arrangements together with an account of the actual progress made. (Sci. Abs. 65B: 24, Jan. 1962)

2830
Bucci, N.W. and Briggs, R.W. ELECTROMAGNETIC POWER SYSTEMS FOR SPACE APPLICATIONS. 8p., New York, American Rocket Society, 1961. (Tech. paper 61-188-1882)

Discusses factors affecting the selection and design of an electric generator, its controls, and conversion equipment. It is pointed out that to realize a space power system in the megawatt range which will be a compact and lightweight apparatus will require much research. (Index Aero. 17:124, Oct. 1961)

2831
Cooley, W.C. SOLAR DIRECT-CONVERSION POWER SYSTEMS. Inst. Radio Engrs. Trans. MIL-6: 91-98, illus., Jan., 1962.

A survey is made of the present status of technology of solar photovoltaic, photoemissive, thermoelectric and thermionic power systems for spacecraft. The subjects of radiation damage to solar cells, power-system design, and solar simulation are reviewed. Various types of solar power systems are discussed and compared with respect to weight, availability, environmental tolerance, and cost. It is concluded that solar photovoltaic and solar

thermionic systems are most desirable for power levels up to 3 kw. However, the life capability of thermionic converters has not yet been established. Solar thermoelectric and photoemissive systems will be less desirable because of their lower efficiency and, therefore, larger area per unit power output, except for missions where radiation resistance or economy are paramount considerations.

2832
ENGINEERING HIGHLIGHTS 1962 IRE CONVENTION. Electron. 35:51-55, illus., Mar. 9, 1962.

The article summarizes papers that indicate some new directions for the second half century of the profession of radio engineering. Featured are biological power supplies, semiconductors, thermoelectric and atomic power, among other developments.

2833
FLIGHT VEHICLE POWER BUDGET CLIMBS. AIR FORCE CAREFULLY EVALUATES 1000 PROPOSALS YEARLY, ACCEPTS 10%; INDUSTRY SHOULD BE 'ENERGY'-, NOT 'POWER-CONSCIOUS'. Missiles and Rockets 10:74-78, illus, Mar. 26, 1962.

Some details are given of the make-up of the AF Flight Vehicle Power Branch and its interests, e.g., thermionics, fuel cells, solar cells and MHD, and batteries, as well as thermoelectric generators.

2834
Heikes, R.R. SCIENCE AND ENGINEERING OF THERMOELECTRICITY. New York, Interscience Publishers, 1960.

The following topics are discussed: thermionic engines- high vacuum; thermionic engines - low pressure; magnetohydrodynamic converters; semiconductor devices; fuel cells.

2835
Herner and Co., Washington, D.C. BASIC RESEARCH RESUMES 1960. A SURVEY OF BASIC RESEARCH ACTIVITIES IN THE OFFICE OF AEROSPACE RESEARCH. 389p., June 1961. (AFOSR 925) (Contract AF 49(638)-903).

Abstracts are presented of unclassified basic research projects supported by OAR.

The sections on solid state sciences, and on energy conversion, transfer and release contain resumes of contracts related to thermoelectricity, solar cells, photovoltaic effect, and magnetohydrodynamics.

2836
Heywood, Harold. NEW SOURCES OF ENERGY. Nature 192:407-408, Nov. 4, 1961.

A general review is presented of outstanding papers given at the United Nations Conference on New Sources of Energy, Rome, August 1961.

2837
Hoh, S.R. FERROELECTRIC ENERGY CONVERTERS. Elec. Comm. 37:22-26, 1961.

Ferroelectric energy converters offer unique characteristics such as high alternating and direct voltages. This contrasts to existing heat-to-electricity converters such as thermoelectric and thermionic types. Conversion efficiency and cost are lower and the output per unit weight apears high.

2838
Huth, J.H. POWER SYSTEMS. STATE OF THE ART - 1961. Astronautics 6:46-47, 96-98, 100, Dec., 1961.

Discussed are: thermocouples; thermionic converters; solar cells; magnetohydrodynamics; fuel cells and batteries; and battery performance.

2839
Khanna, M.L. THE GREEK CONFERENCE IN REVIEW. Sun at Work 7:7-19, First Quarter 1962.

Papers given at the International Seminar on the Application of Solar Energy and Aeolian Energy held at Athens, Greece, September 4 to 15, 1961 are reviewed.

2840
Lauck, Francis, Ulehara, O.A. and Myers, P.S. ENGINEERING EVALUATION OF ENERGY CONVERSION DEVICES. Mach. Design 34: 136, 138, 140-143, illus., Feb. 1, 1962.

A comparison of energy-converting devices is presented based on ultimate efficiency, weight, size, and cost.

2841
Levine, S.N. ed. SELECTED PAPERS ON

NEW TECHNIQUES FOR ENERGY CONSION. 444p., New York, Dover Publications, Inc., 1961.

37 papers for the period 1954-1959 have been selected for inclusion in this volume. All have appeared in various periodicals and relate to thermoelectric methods; thermionic, photovoltaic and electrochemical effects; and fusion.

An introductory statement of 17 pages "sets the stage" for the various contributions.

2842
Linden, David. NEW POWER SOURCES AND ENERGY CONVERTERS. Electron. 35: 35-42, illus., Apr. 6, 1962.

Chemical batteries, fuel cells, photovoltaic converters, nuclear energy systems, and thermal energy conversion are discussed.

2843
Marvin, Chester. THERMODYNAMICS OF A SUPERCONDUCTING ENERGY CONVERTER. J. Appl. Phys. 33:643-647, figs. Feb. 1962.

A thermodynamic analysis is given for an energy conversion process which employs the phase transition in a superconductor. The conversion process is a cyclic one. An expression for the conversion efficiency is obtained. Quantitative estimates are calculated from the formula for several superconducting materials. These indicate that conversion efficiencies as high as 44% may be obtainable under ideal conditions.

2844
Mason, J.F. and Wolff, M.F. MISSILE AND SPACE ELECTRONICS. Electron. 34: 87-118, illus., Nov. 17, 1961.

Power generation (solar, nuclear and chemical) is discussed on p. 106-107. A figure depicts estimated electric power requirements for NASA spacecraft through 1965.

2845
Massachusetts Institute of Technology. Research Laboratory of Heat Transfer in Electronics, Cambridge, Mass.
ANALYSIS AND EXPERIMENTAL RESULTS OF A DIODE CONFIGURATION OF A NOVEL THERMO ELECTRON ENGINE, by G.N. Hatsopoulos and Joseph Kaye. 23p., Apr. 21, 1962. (RLHTE-15)
Also in Inst. Radio Engrs. Proc. 46:1574-1579, Sept., 1958.

A small, experimental heat engine is described which uses an electron gas to convert heat to electrical energy with no moving mechanical parts.

2846
Massachusetts Institute of Technology, School of Engineering, Cambridge, Mass.
RESEARCH ON MATERIALS, PROCESSES, AND DEVICES RELATED TO ENERGY CONVERSION, by D.C. White and J. Blair. 95p., Sept. 30, 1961. (Semiannual Tech. Summary Rept. 1) (Contracts Nonr-1841(78); AF 19(604-4153; AF33(616)-7624). (AD-267028).

This is a report on interdisciplinary research comprising thermoelectricity, high-temperature metallurgy, thermionic conversion, and superconductivity.

2847
Meier, David. SEARCH FOR NEW SOURCES OF POWER. Sci. Dig. 50:77-79, Dec., 1961.

A general article directed mainly to the search for low cost power for underdeveloped areas. Mention is, however, made of the progress in use of solar batteries for space missions, and the advantages of fuel cells.

2848
NASA APU'S. AUXILIARY POWER R & D FUNDING UP 88%. Missiles and Rockets 9:66-67, Nov. 27, 1961.

A table lists items in the space power technology budget for 1962.

2849
National Academy of Sciences, National Research Council. Materials Advisory Board, Washington, D.C.
REPORT BY THE COMMITTEE ON MATERIALS ASPECTS OF AUXILIARY POWER UNITS FOR USE IN SPACE VEHICLES OF THE MATERIALS ADVISORY BOARD. 150p., illus., Oct. 25, 1961. (Rept. MAB-177-M) (Contract DA36-039-sc-76436)

A survey was made of the field of energy conversion as applied to generation of power for space vehicles and was completely oriented toward the delineation of those materials research problems which must

be solved in order to provide reliable and efficient systems. Chemical, solar, and nuclear energy sources are reviewed. Mechanical thermionic, thermoelectric, photovoltaic and direct conversion techniques and associated problems of ancillary systems of collectors, radiators, and storage devices are reported.

2850
Naval Civil Engineering Laboratory, Port Hueneme, Calif.
UNFUELED POWER SUPPLY FOR ISOLATED BASES ON SEA ICE, by C.W. Terry. 18p., Oct.12,1961. (Tech.Rept. 163)

Three sources of energy which exist in polar regions were investigated: temperature differential between water and air; wind or air in motion; and solar energy (during summer months).

2851
NEW SOURCES OF ENERGY. THE UNITED NATIONS CONFERENCE IN ROME, 21st-31st AUGUST 1961. Inst.Elec.Engrs.J., 7: 605-606, Oct.1961.

Brief summaries are given of the proceedings in which solar energy and its possible applications was one of the subjects under discussion.

2852
O'Connor, J.J. ENERGY SYSTEMS IN SPACE. Power 106:57-64, illus., Apr.,1962.

Auxiliary electric power applications are mentioned with a comparison of today's silver-zinc cells used in the Mercury capsule with increased needs of future space flights. It is stated that both Gemini and Apollo manned missions will get drinking water as by-product of their electric-generating fuel cells. Solar energy is dropping in favor as man considers flight to Mars and further. Nuclear energy appears most practical source.

2853
Power Information Center, University of Pennsylvania, Phila., Pa.
ANNUAL REPORT, August 1, 1960 to July 31, 1961. 29p., 1961. (Annual Rept.1) (Contract DA 36-039sc-85371)

Activities are reported for PIC, established August 1960 to function as an agency of the Interagency Advanced Power Group(IAGP); as a technical information center for power R.D. & E., and as a secretariat of IAGP.

2854
Power Sources Conference. PROCEEDINGS, 15th, 1961. 162p.,illus. Red Bank, N.J., PSC Publications Committee, 1961.

For analysis of contents see entries for: Agruss, B., Angello, J.; Baum, E.A.; Bone, J.S.; Chapman, L.E.; Cohn, G.; Elliott, J.F.; Gregor, H.P.; Grimes, P.G.; Hall, W.B.; Herchakowski, A.; Holechek, J.J.; Holland, H.W.; Lamond, Pierre; Lee, J.M.; Ludwig, F.A.; Mandelkorn, J.; Mann, A.E.; Moreland, W.C.; Rusinko, Frank, Jr.; Silverman, H.; White, D.C.; and Winckler, G.A.F.

2855
Reid, W.T. and Edson, A.P. ELECTRIC POWER SOURCES OF THE FUTURE. 19p., New York, International Nickel Co., 1961.

Paper prepared for the International Nickel Company Power Conference, Estes Park, Colo., 1 Aug. 1961. (Unpublished paper)

Reviews developments in the production of electricity using: nuclear power, solar batteries, fuel cells, thermoelectric, thermionic, and magnetohydrodynamic generators.

2856
SPACE POWER FUND REQUEST UP1/3. Missiles and Rockets 10:34, Apr.9,1962.

Proposed work on solar cells, fuel cells, thermonics and solar concentrators is listed.

2857
Steinhilper, W. ENERGY PROBLEMS AND POSSIBILITIES FOR THE DIRECT ECONOMICAL GENERATION OF ELECTRICAL ENERGY. Europ.Mach.Rev. 11:20-25,1961.

Direct methods of generating electrical energy without the use of fossil fuels are reviewed briefly. (Fuel Abs.& Current Titles 2:6782, 1961)

2858
Thornbury, J.W. EXOTIC POWER SOURCES. Am.Soc.Nav.Engrs.J., 73:647-653, Nov. 1961.

This paper is limited to new power sources

not now being used in ships but which might possibly be used in marine propulsion plants in the future, and is further limited to systems which have already produced controlled power even though in limited amounts and of short duration.

Schemes examined are thermionic converters, magnetohydrodynamics, thermoelectric conversion, and fuel cells.

2859
U.S. Army. Signal Research and Development Laboratory, Ft. Monmouth, N.J. SPACE POWER RESEARCH AND DEVELOPMENT. Quarterly Progress Reports. 6 issues, Sept., Dec. 1960, Mar., June, Sept. Dec., 1961.

Details of contracts under the direction of USASRDL concering solar cells, solar converters, and fuel cells.

2860
Yellott, J.I. SOLAR ENERGY PROGRESS REPORT - 1961. Am. Soc. Mech. Engrs. Trans. Ser. A. J. Eng. for Power 84:213-221, Apr., 1962.

The paper is divided into several parts: Solar energy meetings and publications in 1961; Solar energy developments for terrestrial applications (vapor cycles for small solar power plants,) developments in solar-electric systems (photovoltaic cells, thermoelectric generators, thermionic converters), solar water heaters, space heating, cooking, solar furnaces, etc.; For the future (refrigeration by solar energy, new materials in solar energy utilization, heat storage, solar power systems for space stations).

2861
White, D.C., Wedlock, B.D. and Blair, John. RECENT ADVANCE IN THERMAL ENERGY CONVERSION. In Power Sources Conference. Proceedings, 15th, 1961, p.125-132, figs., Red Bank, N.J., PSC Publications Commitee, 1961.

The state of the art in thermoelectric materials and generators, thermionic converters, MHD power generation and photovoltaic converters is presented.

2862
Wright, D.A. UNCONVENTIONAL METHODS OF ENERGY CONVERSION. Nature 192: 701-703, Nov. 25, 1961.

Brief summaries are given of papers by T.G. Cowling, F.H.S. Brown, R.G. Siddall, P. Dunn and D.A. Wright presented at a joint session of Sections A (Mathematics and Physics) and G(Engineering) of the British Association. The meeting was held to discuss the present situation with conventional methods of converting heat into electricity, the need for new methods, the principles of the new methods on which research is in progress, and the prospects for the future.

2863
Zahl, H.A. and Ziegler, H.K. POWER SOURCES FOR SATELLITES AND SPACE VEHICLES. IGY Ann. 12(pt.II):924-935, 1961.

Discussion of three types of power sources for space applications. These are: chemical batteries, solar energy converters, and nuclear power devices. The energy systems are evaluated as two distinct categories: (1) those that carry their own source of primary energy, and (2) those which take advantage of natural energy sources which exist in the universe. (Intern. Aerospace Abs. 1:61-8200).

2864
Zalar, S.M. DIRECT HEAT-TO-ELECTRICITY ENERGY CONVERTERS. Electron. World 67:39-41, 85-87, figs., May 1962.

A survey of unconventional energy sources that produce electricity without the use of moving parts or batteries.

B. Bibliographies

2865
Brimelow, T. SOLAR ENERGY TECHNOLOGY 1954-1959. 32p., London, The Library Association, 1961.

According to the compiler, this has been an attempt to list (without abstracts) all the significant literature on the subject published in Europe and U.S.A. There are 327 references arranged by subjects such as aero/space applications; air conditioning; electrical conversion; power generation; furnaces; heating; heat pumps; and refrigeration.

2866
California Institute of Technology. Jet Propulsion Laboratory, Pasadena, Calif. THERMIONIC AND THERMOELECTRIC

CONVERSION SYSTEMS, compiled by Edda Barber. 48p., Mar. 1962. (Lit. Search 392) (Contract NAS 7-100)

The 292 annotated references supplement those appearing in Literature Search 294, Thermionics and Electricity, issued December 1960.

2867
Library of Congress. Air Information Div., Science and Technology Section, Washington, D.C.
SOURCES AND CONVERSION OF ENERGY IN SPACE-VEHICLE POWER SYSTEMS. A REVIEW OF SOVIET OPEN LITERATURE. 27p., Jly. 26, 1961. (AID Rept. 61-104) (Rept. 1 for 1958-1960) (AD 261 456)

Contents: Early research and development (semiconductor research, theoretical and experimental work, solar batteries, thermoelectric power, nuclear batteries); Current developmental trends) research problems in thermoelectricity, utilization of solar energy, use of atomic batteries, current studies); Research on power-system semiconductor materials (general considerations, purification of semiconductor materials, physical and chemical characteristics of semiconductors); The search for new materials.

2868
Lockheed Aircraft Corp., Sunnyvale, Calif. PHOTOVOLTAIC CELLS. AN ANNOTATED BIBLIOGRAPHY, by M. A. Pearcy. 2 vls., Aug., Dec., 1961. (Spec. Bibl. 60-26 and 60-28)

The first volume presents a general survey of the literature from 1910 to 1960. The second volume, or supplement, is a more inclusive treatment of the 1959 and 1960 literature.

2869
Merkulov, V.S. ATOMIC BATTERIES (WITH BIBLIOGRAPHY). Izmeritel. Tekh. no. 2, 94-97, Mar/Apr. 1958.

Not examined. In Russian

Trans. available from Joint Publications Research Service, New York, Pub. 791. (PB 141 480-T)

2870
Office of Technical Services, Washington, D.C. THERMOPILES AND THERMOCOUPLES. 7p., Aug. 1960. (Spec. Bibl. 430)

Covers 1950-1960. References, some with abstracts, to about 60 U.S. Government reports and 12 translations (mainly from the Russian).

2871
Veinberg, V.B. OPTICS IN EQUIPMENT FOR THE UTILIZATION OF SOLAR ENERGY. LITERATURE CITED. 15p., Washington, D.C., U.S. Atomic Energy Commission, Feb. 1962. (Trans. 4471(Addendum))

Several hundred references are cited in this translation from Optika v Ustanovkakh Diya Ispol'zovaniya Solnechnoi Energii, p. 225-233.

2872
SEMICONDUCTOR ABSTRACTS, v. VI and VII, 1958 and 1959. J.J. Bulloff and C.S. Peet, eds., compiled by Battelle Memorial Institute under the auspices of the Electrochemical Society, Inc., Sponsored by Air Force Office of Scientific Research and Battelle Memorial Institute. 2v., New York, Wiley, 1961, 1962.

Included are a number of references, with abstracts which relate to thermoelectricity.

C. Patents

2873
Blackmer, R.H. FUEL CELL SYSTEM WITH MEANS FOR PREVENTION OF DAMAGE BY DIFFERENTIAL GAS PRESSURES. U.S. Patent 3, 014, 976 (to General Electric Co.), Feb. 29, 1960.

A fuel cell system comprising, in combination; a fuel cell comprising a pair of electrodes, an electrolyte membrane positioned between and in contact with said electrodes, and means forming a pair of chambers each enclosing one of said pair of electrodes, means for supplying fuel and oxidant reactant gases to said chambers, respectively; and means responsive to a reference pressure constructed and arranged to flood one of said chambers with a non-reactant fluid upon the pressure of the reactant gas in said one chamber decreasing to a value less than said reference pressure. (U.S. Patent Off. Off. Gaz. 773: 1119, Dec. 26, 1961).

2874
Busanovich, C.J. THERMOELECTRIC MA-

TERIALS AND ELEMENTS UTILIZING THEM. U.S. Patent 2,902,529 issued Sept. 1, 1959.

The preparation of n-type Bi_2Te_3 alloys with high thermoelectric power is described. (Semiconductor Electron. 3:5603, Jan. 1960).

2875

Cornish, A.J. and Miller, R.C. THERMOELECTRIC MATERIALS. U.S. Patent 3,018,312 (to Westinghouse Electric Corp.) Aug. 4, 1959.

In a thermoelectric device a first member consisting of a homogeneous essentially single phase crystalline material having a formula $Ge_{1-x}A_xTe_{1\text{ to }1.06}$ wherein A is at least one element selected from the group consisting of bismuth, gallium, indium, iron, scandium, lanthanum, lead, yttrium, ruthenium, and thallium, and x is at least 0.001 and not more than 1.15, and a second member electrically connected to one portion of said first member. (U.S. Patent Off. Off. Gaz., 774:916, Jan. 23, 1962)

2876

Fredrick, R.E. THERMOELECTRIC ALLOYS AND ELEMENTS. U.S. Patent 3,020,326 (to Minnesota Mining and Manufacturing Co.) Aug. 21, 1958.

A thermoelectric alloy consisting essentially of 60.01 to 61.16 atomic percent tellurium, substantially all of the balance being an antimony-bismith constituent containing 65 to 90; atomic percent antimony. (U.S. Patent Off. Off. Gaz. 775:246, Feb. 6, 1962)

2877

Fritts, R.W. and Karrer, Sebastian. ELECTRICAL DEVICE. U.S. Patent 3,022,361 (to Minnesoto Mining and Mfg. Co.), Oct. 24, 1956.

A thermoelectric generator comprising a semi-metal thermoelement having a contacting surface, a contact electrode of metal compatible with said semi-metal and having a contacting surface, an hermetically sealed enclosure for said thermoelement and contact electrode, said enclosure including as part thereof an enclosure member having a fused electrically and thermally conductive connection with said contact electrode, and biasing means placing said thermoelement and electrode contacting surfaces in continuous low electrical resistance pressure contact, said enclosure member being made of a metal oxidizable to form a refractory oxide and having a surface portion exposed within said enclosure beyond said thermoelement contacting surface in the direction of said contact electrode, the metal of said contact electrode being oxidizable to form an oxide which is more readily reducible than said refractory oxide, wherefore upon occurrence of moisture within said enclosure, reaction thereof with said enclosure member forms refractory oxide and liberates hydrogen which, upon reaction with any oxide of the metal of said contact electrode, reduces said last-mentioned oxide to thereby protect the interface of said pressure contact therefrom and minimize the electrical resistance of said pressure contact. (U.S. Patent Off. Off Gaz., 775:843, Feb. 20, 1962).

2878

Fritts, R.W. THERMOELECTRIC GENERATOR. U.S. Patent 3,023,257 (to Minnesota Mining & Mfg. Co.), May 29, 1958.

In a thermoelectric generator, the combination of a plurality of parabolic segment members joined along their edges to form a parabolic reflector, a plurality of thermoelectric assemblies each mounted at the abutting edges of a separate pair of said parabolic segment members, and said thermoelectric assemblies, each comprising thermoelectric element means having hot and cold thermojunctions, each of said thermoelectric assemblies having their hot thermojunctions disposed substantially at the focus point of the parabolic segment member opposite the abutting edges between which said thermoelectric assemblies are mounted. (U.S. Patent Off. Off. Gaz. 775:1098, Feb. 27, 1962).

2879

Goldsmid, H.J. and Sheard, A.R. PREPARATION OF MATERIAL FOR THERMOCOUPLES. U.S. Patent 3,017,446 (to General Electric Co., Ltd.), Dec. 16, 1957.

A method of preparing thermocouple elements which consist essentially of a semiconductor having a constitutional formula $Bi_mSb_nTe_pSe_qS_r$ (where n has a value in the range 0-1.8 q has a value in the range 0-0.4 and r has a value in the range 0-0.24, subject to the conditions that m+n=2, p+q+r=3, 3n+2q+2r is not less than 0.03, and 3q+5r is not

greater than 1.2): said method comprising the steps of, melting together in vacuo the constituent elements of the semiconductor in appropriate proportions, producing from the molten material an elongated solid ingot, subjecting the ingot to zone melting, and then cutting the thermocouple elements from the ingot with that dimension of each element which is to extend between the junctions of a thermocouple parallel to the longitudinal axis of the ingot. (U.S. Patent Off. Off. Gaz. 774:665, Jan. 16, 1962).

2880

Goldsmid, H.J. and Sheard, A.R. THERMOCOUPLES UTILIZING SEMICONDUCTORS OF THE BISMUTH TELLURIDE TYPE. U.S. Patent 2,990,439 (to General Electric Co., Ltd.), June 27, 1961. (Abs. in Chem. Abs. 55:22956, 1961).

2881

Houston, M.D. THERMOELECTRIC MATERIAL AND DEVICES. U.S. Patent 3,009,977 (to Westinghouse Electric Corp.), Aug. 14, 1959.

In a thermoelectric power generating device at least one pair of joined members, one being a member comprised of a material having the formula $MS_{y-x}Se_x$, wherein M represents at least one element selected from the group consisting of lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutecium, y varies from 1.0 to 0.5 and x varies from 0 to 0.2, and another suitable member electrically connected to one portion of said one member. (U.S. Patent Off. Off. Gaz. 772:840, Nov. 21, 1961).

2882

Hughes, H.D., Lewis, R.W., and Partridge, A.H. ELECTRIC PRIMARY CELLS. U.S. Patent 3,026,365 (to Metachemical Processes, Ltd.), Mar. 17, 1959.

An electric primary cell comprising a hermetically sealed outer casing, a cathode and an anode accommodated within said outer casing, said anode and said cathode each including a support surface formed of expanded metal and each having an integral extension connection member also formed of the same expanded metal leading to the outside of said casing in sealed relation thereto, an active covering on said anode including a foil selected from a material containing a range of 90 to 99% indium and 10 to 1% bismuth, both metals being of high purity and containing not more than 0.1% total of impurities and an alkaline solution electrolyte within said outer casing. (U.S. Patent Off. Off. Gaz.; 776:884, Mar. 20, 1962)

2883

Hunt, L.B. and Connor, Henry. IMPROVEMENTS IN AND RELATING TO THERMOCOUPLES. British Patent 876,553, Sept. 6, 1961. (to *Johnson, Matthey, and Co., Ltd.*)

Thermocouple suitable for use at high temperatures and under neutron irradiation conditions such as in reactors may be fabricated using two Pt-Mo alloys, one containing 3 to 6 wt.% Mo and the other 0.01 to 1 wt.% Mo. The resulting Pt-Mo/Pt-Mo thermocouple has a lower neutron capture cross section than a Pt/Pt-Rh thermocouple, but is not as oxidation-resistant and hence should be used in neutral or reducing atmospheres. (Nuclear Sci. Abs. 16:2012, Jan. 31, 1962)

2884

Janca, M. THERMOELECTRIC APPARATUS FOR SORTING STEEL. Czechslovakian Patent 89985, May 15, 1959.

A patent has been taken out for a thermoelectric apparatus for sorting machine, alloy and high-speed steels. The apparatus is based on measurement of the thermoelectric force which is produced in the heated contact between the examined and standard specimens of the steel. The apparatus consists of a probe heated by an electric coil and made from the standard material, and of a contact probe from the same material, which is connected to the 1st probe through a sensitive galvanometer. The suggested method is advantageous because it permits to measure specimens of any size. (Abs. J. Metall. nos. 11/12, (Part A), 571, 1960)

2885

Justi, Eduard and Neumann, Georg. METHOD FOR PRODUCING THERMOELECTRIC COMPONENTS ON ZINC-ANTIMONY BASIS. U.S. Patent 3,021,378 (to Siemens-Schuckertweke, Aktiengesellschaft, Berlin), Mar. 16, 1960.

The method of produing a thermoelectric component from a compositon of the system $Zn_xCd_{1-x}Sb$ wherein x is larger

than zero but not larger than unity, which comprises melting the composition, freezing the melt and thereafter tempering it in the solid state for more than one hour a at a temperature between about 741°K and 778°K corresponding substantially to the conversion temperature of the composition as manifested by a discontinuity point of its conductance-temperature characteristic. (U.S. Patent Off. Off. Gaz. 775:565, Feb. 13, 1962).

2886

Justi, Eduard. THERMOCOUPLES, PARTICULARLY FOR THE PRODUCTION OF COLD, AND METHODS OF THEIR MANUFACTURE. U.S. Patent 2,877,283 issued Mar. 10, 1959.

An ultrasonic tinning technique, applicable to tinning Bi_2Te_3, BiSb, and CdSb thermoelements, as well as other oxide coated semiconductors, is described. The work, in a suitable holder, is lowered into an ultrasonically activated solder pot contained in a gastight box with a non-oxidizing atmosphere. Bi, Cd, or Sn solder may be used, depending on the metal in the element. Elements thus tinned have no intermediate oxide layer and consequently, a higher efficiency is obtained. In one thermoelectric cooler design, elements are soldered to opposite sides of a copper sheet heat sink. (Semiconductor Electron. 3:5451, Jan. 1960).

2887

Long, E.S. PRIMARY CELL. U.S. Patent 3,015,681 (to Hamilton Watch Co.), Nov. 6, 1958.

A primary cell comprising a container; and anode and a cathode in said container; an alkaline electrolyte in said container; and a barrier membrane formed of a sulfonated polymer of the cation exchange type separating said anode and cathode and in contact with said electrolyte; the alkaline concentration of said electrolyte being sufficiently great to induce said barrier membrane to exercise substantially no permselective effect in the reaction in said cell. (U.S. Patent Off. Off. Gaz. 774:164, Jan. 2, 1962).

2888

Panchenko, Ye.V. and Strug, Ye.M. AN INSTRUMENT FOR STUDYING LOCAL THERMOELECTRIC PROPERTIES OF ALLOYS. USSR Patent 128256, Apr. 28, 1960.

A description is given of an instrument for studying local thermoelectric properties of alloys, consisting of a contact device, an optical attachment for locating the microsurface being examined, a thermocouple, a heating element and an electrical measuring apparatus. The contact device is made in the form of a centred metallic needle passing through a tubular electric-resistance microfurnace; a junction of the contact thermocouple is soldered on to the end of the needle. (Abs. J. Metall. A. nos. 3/4:515, 1961).

2889

Pietsch, J.A. THERMOELECTRIC ASSEMBLY. U.S. Patent 3,022,360(to General Electric Co.), Nov. 25, 1960.

A thermoelectric junction for a heating or cooling device utilizing the Peltier effect comprising a tubular shaped thermoelectric element having at least one open end, an electrical current and thermal conductor link having an annular groove adapted to receive said open end of said tubular shaped thermoelectric element with the sides of said annular groove encompassing the inner and outer surface of said end of said tubular-shaped thermoelectric element, and solder means of high electrical and heat conductivity in said annular groove around the inner and outer surface of said end of said tubular shaped thermoelectric element for securing said open end of said thermoelectric element within said groove in said conductor link. (U.S. Patent Off. Off. Gaz. 775:843, Feb. 20, 1962).

2890

Ralph, E.L. FLEXIBLE SOLAR ENERGY CONVERTER PANEL. U.S. Patent 3,025,335(to Hoffman Electronics Corp.). Feb. 29, 1960).

A method comprised of: Partially imbedding a plurality of semiconductor pieces in a transparent, flexible non-conductive material, each piece having an outer first-type conductivity region and an inner second-type conductivity region; making an ohmic contact to each of said first-type conductivity regions; depositing a flexible metal film so as to electrically connect together all of said ohmic contacts; covering said film with a flexible insulating material so as to electrically insulate said pieces from each other; removing said outer first-type conductivity regions from the ends of said pieces opposite said transparent material, thereby exposing said inner second-type con-

ductivity regions so as to face in generally the same direction; etching away a portion of said first-type conductivity regions underneath said insulating layer in the direction towards said transparent layer to prevent a short circuit from occurring; covering said first-conductivity type regions with said insulating material so that they are not longer exposed; making an ohmic contact to each of said second-type conductivity regions; and depositing a flexiblemetal film so as to electrically connect together each of said ohmic contacts associated with said second-type conductivity regions.

2891

Rosi, F.D. THERMOELECTRIC COUPLE. U.S. Patent 2,902,528, Issued Sept. 1, 1959.

The preparation of an n-type bismuth telluride-bismuth selenide thermoelectric alloy is described Bi, Te, and Se are heated with either copper sulfide or silver sulfide at about 750°C for about six hours and slowly cooled. For the preparation of an alloy consisting of 75 per cent Bi_2Te_3 and 25 per cent Bi_2Se_3 with a charge carrier concentration of 10^{18}-$10^{20}cm^{-3}$, the following constituents are utilized: 40 gms Bi, 27.50 gms Te, 5.67 gms Se, and 0.1 to 0.25 gms copper sulfide or, silver sulfide. (Semiconductor Electron. 3:5604, Jan. 1960).

2892

Ross, N.V. HIGH-TEMPERATURE THERMOCOUPLE DEVICE. U.S. Patent 3,016,412 (to Ajax-Magnethermic Corp.), Mar. 27, 1958.

A thermocouple device including a body having a forward wall adapted to be juxtaposed against the surface of an article of which the temperature is to be measured and having a relatively shallow end cavity facing forwardly toward said wall, a thermocouple including a relatively small, unitary thermocouple junction positioned in the cavity so as to be responsive to heat conditions created in the cavity, said junction being positioned, endwise of the cavity, inwardly from, and in closely spaced relation to the forward end so as to be in closely spaced relation to said surface of the article when the wall of the body is so juxtaposed, and, in addition to said junction, a heat conducting shield member of non-thermoelectric material having a portion in intimate heat conducting relation to the junction and disposed forwardly thereof and extending outwardly, transversely of the cavity, therefrom, and sealing the cavity forwardly of the junction, said shield member having a forward face exposed in, and facing toward the forward end of the cavity, and spaced rearwardly from said forward end and rearwardly from said juxtaposed wall and said junction is juxtaposed against the rear face of the shield member. (U.S. Patent Off. Gaz. 774:371, Jan. 9, 1962).

2893

Ruetschi, Paul. FUEL CELLS AND THEIR ELECTRODES. U.S. Patent 3,020,327, (to Electric Storage Battery Co.), Aug. 11, 1959.

A fuel cell electrode comprising a porous matrix at least the pore surfaces of said matrix consisting of a nickel-silver alloy in which nickel is present in an amount by weight of the alloy of from 10% to 50% and silver is present in an amount by weight of the alloy of from 90% to 50%. (U.S. Patent Off. Off. Gaz. 775:247, Feb. 6, 1962).

2894

Thring, M.W. IMPROVEMENTS RELATING TO THE GENERATION OF ELECTRICITY. British Patent 870,446, (to National Research Development Corp.), June 14, 1961.

A method for generating electricity is described which converts the kinetic energy of a reactor coolant directly into electric current. In this method, the coolant, preferably an inert gas such as argon, is passed from a reactor through a magnetic field in a nozzle, and the resulting electric current is collected by spaced electrodes. The reactor is a latticed pile of unprotected uranium oxide and graphite moderators operated at 2000°C. The coolant is at atmospheric pressure and contains some gaseous fission products which ionize the coolant. This method offers the possibility of electricity generation at an efficiency of 50 to 60% as compared with 25 to 30% efficiency using steam as an intermediate stage. (Nuclear Sci. Abs. 15:27232, 1961).

2895

Vahldieck, N.P. FUEL CELL. U.S. Patent 3,013,086, (to Allis-Chalmers Manufacturing Co.), Jly. 17, 1957.

A fuel cell unit adapted to be laminated with like cell units to constract a fuel cell battery, said fuel cell unit comprising: a centrally disposed solid electrolyte con-

structed in the form of a platelike equilibrated gas impermeable and ion permeable membrane, a first platelike electrode formed of a gas permeable and conductive material and laminated on one side of said membrane, a second platelike electrode formed of a gas permeable and conductive material and laminated to the side of said membrane, a spacer plate laminated to the side of each of said electrodes remote from said electrolyte, and a plurality of discrete ports defined through said spacer plates, said electrodes and said electrolyte in alignment with each other and coacting to define a plurality of discrete passages there through, one pair of said passages being communicable with said first electrode, and not said second electrode, to permit the flow of an oxidizing gas there between in contact with said first electrode, another pair of said passages being communicable with said second electrode, and not said first electrode, to permit the flow of a fuel gas here-between in contact with said second electrode. (U.S. Patent Off. Off. Gaz. 773:260, Dec. 5, 1961).

2896

Vyselkov, A. A. and Rogova, G. I. PRIMARY ELECTROCHEMICAL CELL. USSR Patent 109, 345, Feb. 25, 1958.

Fresh water, sea water, or aqueous chloride solutions are used as the electrolyte. The negative electrode is made of Mg or its alloys, and the positive electrode is made of $PbCl_2$. The positive electrode contains carbon black and graphite.

2897

Wildi, B. S. THERMOELECTRIC DEVICE. U.S. Patent 3, 009, 976 (to Monsanto Chemical Co.), June 1959.

In a thermoelectric device, the improvement comprising a polyphthalocyanine body as a thermoelectric component in said device, and electrical connections to said body. (U.S. Patent Off. Off. Gaz. 772:840, Nov. 21, 1961).

2898

Winckler, G. A. F. THERMOELECTRIC DEVICE. U.S. Patent 3, 020, 325 (to United Nuclear Corp.), Nov. 3, 1958.

A thermoelectric generator comprising a non-conducting heat resistant collar, a plurality of thermoelectric devices positioned within said collar, electrical means to connect said devices in series, each said device including a pair of dissimilar thermoelectric elements spaced apart and mounted in the collar, an intermediate heat conducting element having protuberances at each end and adapted to make slight areal contact at each end of the conducting element with a dissimilar thermoelectric element to form a hot junction, and to create a high temperature gradient in the region of said junction, said heat conducting elements forming a grid within the collar whereby a source of heat within the collar is operative to activate all said devices simultaneously. (U.S. Patent Off. Off. Gaz. 775:247, Feb. 6, 1962).

II. THERMOELECTRICITY

A. General Information

2899

LA CONVERSION TERMOELETTRICA. (THERMOELECTRIC CONVERSION). Tecnica Ital. 26:65-71, Jan/Feb. 1961.

In Italian. Discussion of the principles, methods, and applications of thermoelectric conversion. The Seebeck effect in p- and n-type semiconductors is discussed, and equations for the direct conversion of heat into electricity are presented. Various types of thermoelectric generators are described, with particular attention to flat-plate, cylindrical, and spherical thermocouples. Possible future applications of thermoelectric conversion are considered briefly. (Intern. Aerospace Abs. 1:61-8205).

2900

Egli, P. H. PROGRESS IN THERMOELECTRICITY. Inst. Radio Engrs. Trans. MIL-6:27-34, illus., Jan. 1962.

The absence of moving parts and the simplicity promise high reliability, silence, and long-lived, maintenance-free operation both as a power source and as a heat pump for refrigeration and temperature control. A substantial effort devoted to materials development has produced new semiconductors with an integrated theoretical efficiency of about 20per cent. Small power plants for remote areas and auxiliary power supplies for space vehicles are awaiting engineering improvements, some of which again require improved materials for use as electrical contacts and electrical and thermal insulators. Similarly in refrigeration, important military applications and special commercial devices can

be produced with existing thermoelectric materials when engineering problems and the auxiliary materials problems are solved.

2901
Jaumot, F.E., Jr. POWER CONVERSION: SOLID-STATE DEVICES. In Langmuir, D.B. and Hershberger, W.D. eds. Foundations of Future Electronics, p.275-324, New York, McGraw-Hill, 1961.

Following a definition of the significant thermoelectric effects and the development of the thermodynamic relationships, the efficiency of a thermoelectric generator is derived. From this, a figure of merit for thermoelectric material is obtained, leading to a discussion of the materials problem and its present status. The more practical aspects of the fabrication of materials and the formation of junctions are discussed briefly, followed by a discussion of practical applications of thermoelectric devices. About 125 references published since 1950 are listed.

2902
NEW THERMOELECTRIC DEVELOPMENTS IN RESEARCH AND ENGINEERING SHOW PROMISE. Elec. Eng. 81:32-33, Jan. 1962.

Mentioned are: (1) a thermoelectric material (germanium-silicon-alloy developed by RCA) (2) a propane-fired generator (a portable, 250-watt thermoelectric generator designed to power surveillance radar, communications equipment, and other field gear); and (3) a new manufacturing process (for thermoelectric units using a new material called "Generalock" which aids in eliminating power loss and thus reduces cost).

2903
SUMMARIZED PROCEEDINGS OF A CONFERENCE ON THERMOELECTRICITY, DURHAM, JULY 1961. Brit. J. Appl. Phys. 12:592-594, Nov., 1961.

Summary of the main features of most of the 36 papers presented (no list of papers).

B. Theory

2904
Appel, J. THERMAL CONDUCTIVITY OF SEMICONDUCTORS. In Progress in Semiconductors, v.5, p.141-185, New York, Wiley, 1960.

Thermal conduction and thermoelectric cooling are discussed.

2905
Baranskii, P.I. VOLUME-GRADIENT PHENOMENA AND THE FEASIBILITY OF THE SECOND THERMOELECTRIC RELATIONSHIP. Fiz. Tverdogo Tela 3:1616-1617, May 1961.

In Russian. Trans. in Soviet Phys. Solid State 3:1172-1173, Nov., 1961.

Examples are given to cite feasibility.

2906
Bross, H. and Haecker, W. ERKLAERUNG FUER DAS POSITIVE VORZEICHEN DER THERMOKRAFT VON KUPFER BEI HOEHEREN TEMPERATUREN. (EXPLANATION FOR THE POSITIVE SIGN OF THE THERMOELECTRIC POWER OF COPPER AT HIGHER TEMPERATURES). Z. Naturforsch. 16A:632-634, June 1961.

In German. It is shown from an analysis of lattice vibration spectrum data, that the positive sign of the thermoelectric power of copper is accounted for by a deviation of electronic energy from the hitherto accepted value. (Sci. Abs. 65A:657, Jan. 1962).

2907
Carnegie Institute of Technology. Dept. of Electrical Engineering, Pittsburgh, Pa. THERMOELECTRIC EFFECTS IN IONIC MATERIALS, by R.H. Detig. 109p., Oct. 1961. (Contract Nonr-760(09)).

The purpose of the work has been to study methods for determining, from a theoretical approach, the incremental potential difference per unit temperature difference (normally called thermoelectric power) between the electrodes of ionic thermocells. The thermoelectric power of ionic thermocells is derived from the methods of thermostatics and irreversible thermodynamics. A comparison of the two different applications of these equations to ionic materials is presented.

2908
Drabble, J.R. and Goldsmid, H.J. THERMAL CONDUCTION IN SEMICONDUCTORS. 235p., illus., New York, Pergamon Press, 1961. (International Series of Monographs on Semiconductors).

Appendix I. The Figure of Merit for Thermoelectric Applications, p. 198-202.

2909
Georgia Institute of Technology, Atlanta, Ga. RESEARCH ON VARIOUS PHENOMENA FOR THE PERFORMANCE OF CIRCUIT FUNCTIONS, by E. J. Scheibner. 92p., Mar. 1961. (WADD Tech. Rept. 61-148) (Contract AF33(616)6028)

Thermoelectric effects are discussed, p. 24-31.

A literature survey of 157 annotated articles is arranged according to various groups of solid state effects.

2910
Gilbert, N. E. ELECTRICITY AND MAGNETISM. 3rd. ed. 569p., N.Y. Macmillan, 1950.

Ch. XXIX, Thermoelectricity, p. 507-515.

2911
Guenault, A. M. and MacDonald, D. K. C. ELECTRON AND PHONON SCATTERING, THERMOELECTRICITY IN POTASSIUM AND ALLOYS AT VERY LOW TEMPERATURES. Phys. Soc. Proc. 264A:41-59, figs., Oct. 24, 1961.

An experimental study has been made at very low temperatures of the thermoelectric power of potassium and alloys with sodium, rubidium and cesium as solutes. The results enable a clear separation to be made between the 'electron diffusion' and 'phonon drag' components of thermoelectric power. Comparison of the results with theory has led to a number of useful conclusions about phonon and electron scattering in potassium.

2912
Guenault, A. M. and MacDonald, D. K. C. A NOTE ON THERMOELECTRIC POWER AND INELASTIC SCATTERING. Phil. Mag. 6:1201-1206, figs., Oct. 1961.

Recently, Kasuya, Bailyn and de Vroomen have independently proposed that spin-dependent scattering of electrons by magnetic impurity ions would provide a mechanism to account for the "giant" thermoelectric powers observed in certain dilute alloys at very low temperatures. A simplified model discussed here indicates directly that the essential requirement is that of two largely independent groups of conduction electrons whose mobilities are significantly different, but in which the groups are coupled by (spin-dependent) inelastic scattering. It also follows in general agreement with experiment that resistive anomalies are to be looked for when such "mutual electron-drag" is present.

2913
Gurevich, L. E. and Nedlin, G. M. QUANTUM KINETIC EQUATION IN THE PRESENCE OF MUTUAL ENTRAINMENT OF ELECTRONS AND PHONONS. Zhurn. Eksp. i Teor. Fiz. 40:809-818, Mar. 1961.

In Russian. Trans. in Soviet Phys. JETP 13:568-574, Sept., 1961.

A theory is developed for the thermoelectric coefficients in a quantized magnetic field in the case of mutual entrainment of phonons and electrons. A set of kinetic equations for the phonon distribution functions, and the electron density (non-diagonal) matrix f is obtained with the aid of the diagram technique developed by Kubo. It is shown that solution of the integral equations for g and the diagonal part of f should precede the expansion in powers of $(wr)^{-1}$ 1 (w is the Larmor frequency and r the electron relaxation time). An arbitrary electron and phonon spectrum is assumed.

2914
Haga, Eijiro. THEORY OF THERMOELECTRIC POWER OF IONIC CRYSTALS. IV. Phys. Soc. Japan. J. 15:1949-1954, Nov., 1960.

The thermoelectric power Q associated with the movement of silver ions in Ag_2X (X = S, Se, Te) is discussed, where Q is obtainable by measuring the potential difference between silver electrodes in an arrangement as $Ag(T_1)/AgI(T_1)/Ag_2X/AgI(T_2)/Ag(T_2)$. When a temperature gradient is applied, Q generally changes with time because of the thermal diffusion of both electrons and silver ions, and then reaches its steady value. An explanation on the heat of transport in ionic crystals is given taking into account the variation of vibration frequency of lattice due to the presence of defects. The theory is compared with the experimental data on silver halides and Ag_2X available at present. (Japan Sci. Rev. Mech. & Elec. 7:466, 1961).

2915
Hedgcock, F. T. and Muir, W. B. THERMOELECTRIC EFFECTS IN Mg, Zn AND Al CONTAINING TRACES OF Mn. Phys. Soc. Japan. J. 16:2599-2600, Dec. 1961.

This is a letter, the purpose of which is, firstly, to show qualitatively that the thermoelectric voltage in divalent metal alloys exhibiting low temperature resistance anomalies is the same as the monovalent metal alloys, and secondly, that although the dilute Al-Mn alloys do not show a resistive anomaly they do show a large negative thermoelectric voltage.

2916
Illinois Institute of Technology. Dept. of Chemistry, Chicago, Ill.
ELECTRONIC ENTROPY IN LIQUID METAL SOLUTIONS, by L. M. Webber. 54p., Jan. 1961. (Contract AF 49(638)-346).

Research of this MS thesis is an attempt to arrive at some evaluation of a correlation between the changes of the Seebeck coefficient (thermoelectric power) on the mixing of two components and the electrode entropy of mixing.

2917
Lange, E. PELTIER HEATS AT SIMPLE ELECTRODES. An. Real Soc. Espan. Fis. Quim. 56B:509-514, 1960.

In German. Abs. in C[illegible]. Abs. 55:6970, 1961.

2918
Lidiard, A. B. and Govard, R. DEFECTS IN THE CRYSTAL LATTICE OF DIELECTRICS AND THEIR RELATION TO ELECTRIC CONDUCTIVITY. THERMOELECTRIC EFFECTS. Fiz. Dielektrikov(Moscow. Akad. Nauk. S. S. S. R.) Sbornik 1960, 449-458. (From Referat. Zhur. Khim, 1961, Abs. 7B213).

For abstract see Chem. Abs. 56:4200, Mar. 5, 1962.

2919
Mooser, E. and Pearson, W. B. THE CHEMICAL BOND IN SEMICONDUCTORS. Can. J. Phys. 34 (Suppl. 12A) 1369-1376, Dec. 1956.

Paper given at International Conference on Electron Transport in Metals and Solids, Ottawa, Sept. 10-14, 1956. A brief review is first given of the developments which led to an understanding of the important role played by chemical bonding in semiconductors. The properties of the Group V B to VII B elements and of some compounds formed between these elements are then considered according to the valence bond model of Pauling. This leads to the conclusion that the band scheme in these substances is somewhat different to that which has been generally accepted. The new model is discussed in relation to electrical and optical properties.

2920
Pearson, W. B. SURVEY OF THERMOELECTRIC STUDIES OF THE GROUP-I METALS AT LOW TEMPERATURES. Fiz. Tverdogo Tela. 3:1411-1424, May 1961.

In Russian. Trans. in Soviet Phys. Solid State 3: 1024-1033, Nov. 1961.

The great interest which has been shown in the thermoelectricity of metals at low temperatures in recent years is now, leading to an understanding of the phenomena which is quite encourageing. The initial studies of "phonon-drag" thermoelectricity by Gurevich and the deduction by Kohler of a rule for treating the influence of competing scattering mechanisms on "diffusion thermoelectricity" have done much to promote this understanding. This is discussed in relation to work on the Group I metals carried out at the National Research Laboratories, Ottawa, Canada.

2921
Testardi, L. R. CALCULATIONS OF THE THERMOELECTRIC PARAMETERS AND THE MAXIMUM FIGURE OF MERIT FOR ACOUSTICAL SCATTERING. J. Appl. Phys. 32:1978-1981, figs., Oct. 1961.

The calculations of Chasmar and Stratton (J. Electron. & Control 7:52, 1959) for the determination of the maximum thermoelectric figure of merit are extended for the case of acoustical scattering. Graphical data are presented for the determination of the material parameter, the optimum values of several quantities, and the degradation of the figure of merit for non-optimum conditions. The variations of the Seebeck coefficient and the electrical conductivity computed from exact statistics are compared with experimental results for several alloys of thermoelectric interest. Good agreement is found except for high electrical conductivities. Other anomalies noted.

2922
Thien Chi, N. and Vergnolle, J. SEMICONDUCTOR THERMOELEMENTS AND THEIR APPLICATIONS. Onde Elec. 40: 450-465, June 1960.

In French. The basic facts and laws of thermoelectricity are recalled, and their connection with solid-state physics is sketched. The general operation of a thermocouple is studied theoretically, and six regions of operation are described in detail. The practical rule is deduced, that the power of a thermopile is proportional to its surface and inversely proportional to its thickness. Descriptions are given of laboratory measurements of parameters e, ρ, Z and charge carrier density. Some practical results are quoted. The work has not yet been brought to completion. (Sci. Abs. 64B:5495, 1961).

2923
Thouvenin, Y. A CONTRIBUTION TO THE STUDY OF THE ELECTROLYTIC PELTIER EFFECT OF THE AMALGAM SYSTEM ZINC-ZINC SULFATE. Acad. Sci. Paris. Compt. Rend. 253:117-119, Jly. 3, 1961.

In French. The electrolytic Peltier effect of the amalgam system Zn-ZnS is discussed. The Peltier electrolytic molar specific heat is defined in terms of the reverisible phase change of a mole of electroactive ion and of the potential difference between the two electrodes. The transfer molar specific heat is defined using the reaction absolute temperature and the reaction free chemical enthalpy. The electrodes are considered as open thermodynamic systems, and energy exchanges between the electrodes and their surroundings are taken into account in the derivations, which are based on the Lange theory. Two curves of Zn/Zn^{++} Peltier specific heat in kjoules vs $\log C_{Zn}$ and vs $\log C_{Zn^{++}}$ (i.e., vs amalgam concentration and vs Zn^{++} anion concentration) are presented for T = 30oC. The familar linear plots are obtained. The normal potential of the amalgam system is derived using Nernsl's law. (Solid-State Abs. 2:11, 056, 1961).

2924
Westinghouse Electric Corp. Research Laboratories, Pittsburgh, Pa. COMPUTATION OF EFFICIENCY OF THERMOELECTRIC DEVICES, by B. Sherman, R.R. Heikes, and R.W. Ure. 60p., Mar. 13, 1959. (Sci. Paper 431FD410-P3).

A procedure has been developed for the exact calculation of the efficiency of thermoelectric generators and cooling devices in which the parameters of the materials have arbitrary temperature dependence. High speed computer techniques are found necessary. Approximate methods are reviewed and their discussion extended.

2925
Westinghouse Electric Corp. Research Laboratories, Pittsburgh, Pa. CONSIDERATIONS OF THEORETICAL LIMITATIONS ON THE FIGURE OF MERIT OF A THERMOELECTRIC GENERATOR, by F. Keffer, and A.M. Portis. 11p., Nov. 29, 1954. (Res. Memo. 60-94469-2-M1).

Consideration is given to whether there appears to be any fundamental factors which limit the figure of merit to such low values and the steps that one might reasonably take to develop materials with as high a figure of merit as possible.

C. Related Phenomena

2926
Beskrovnyi, A.K. THE THERMOELECTRIC DETERMINATION METHOD OF THE DIFFUSIONAL ANNEALING TIME OF TIN BRONZE. Zavodskaia Lab. 21:962-964, 1955.

In Russian. A Sn bronze containing 80% Sn and a small amount of Pb was used in the tests. A metallographic examination was used in the preliminary determination of liquation in different parts of the sample. The section was placed in a diffusionmeter with the stationary needle against a Cu disk, and the traveling needle, connected to a micrometer screw, was placed upon the sample surface. The hot junction of the thermocouple was Cu and a Cu-Sn alloy of varying composition. The deflection of the mirror galvanometer increased as the concentration liquation in the alloy increased. After each test, the sample was repolished and annealed at 850° for 30 minutes. The maximum mirror deflections were plotted as a broken line, characteristic of the concentration nonuniformity of the sample, and the arithmetic average of the maximum was found. (Chem. Abs. 50:3173, 1956).

2927
Borzyak, P.H. and Sarbel, O.H. THE EFFECT OF ADSORPTION OF A LAYER OF THE PRODUCTS OF VAPORIZATION OF BaO FROM PLATINUM ON THE WORK FUNCTION OF ELECTRONS FROM GERMANIUM. Ukrain. Fiz. Zhurn. 1:395-402, 1956.

In Ukrainian. By observing the change of contact potential with deposition of the active layer on a Ge single crystal the maximum change of thermoelectric work-function was found viz. 2.6 ev. It is concluded that in the general case of adsorption of active layers the contact potential of a semiconductor must be changed firstly as a consequency of change of surface charge, and secondly, on account of double layer formation. With sufficiently active layers and semiconductors with large so-called "internal work-function" the action of the double layer can overwhelmingly dominate the change of surface charge action, as happens in the present case. (Semiconductor Abs. 6:240, 1958).

2928
Chatterjee, G.P. THERMOELECTRIC PHENOMENA IN RELATION TO STRUCTURAL CHANGES IN METALS AND ALLOYS. Indian Inst. Metals. Trans. 13:315-322, Dec., 1960.

Potentiometric measurements of thermal electromotive force of strip and wire specimens of Al, Cu, Ni, Nichrome, brass steel and Duralumin after annealing, tempering and aging treatments and cold working. Relation of deformation, work-hardening, and heat treatment induced microstructrual changes to thermoelectric properties. (Rev. Met. Lit. 18:35, June 1961).

2929
Fischer, P. THERMOELECTRIC MEASUREMENTS ON UNALLOYED TOOLSTEEL. Harterei-Tech. Mitt. 16:110-112, Jly. 1961.

In German. Investigation of alpha-gamma transitions by thermovoltage measurements on annealed C 100 W 1 Steel and austenitic 18/8 steel wire specimens; and measurement of thermovoltage as influenced by annealing temperature of oil-hardened (790-830°C) C 100 W 1 steel. (ASM Rev. Metal Lit. 18:46, Dec. 1961).

2930
Kunin, N.F. and Afanas'yeva, L.I. THE DYNAMIC EFFECT OF THE [PLASTIC-DEFORMATION] INDUCED THERMO-EMF OF COPPER, ALUMINUM, AND MILD STEEL. Fiz. Met. i Metalloved. 9:24-27, 1960.

In Russian. Trans. in Physics Metal & Metallog. 9(1):20-23, 1960.

It has been shown previously by Kunin and Karelin that the magnitude of the thermo-emf between plastically deformed and annealed Cu depends not only on the degree, but also on the rate of deformation. This "dynamic effect" of the deformation-induced thermo-emf was studied on Cu, Al, and mild-steel specimens, deformed statically and dynamically. The coefficient of the dynamic effect, defined as $k = e_a/e_{st}$, where e_a and e_{st} are the thermo-emf due to dynamic and static deformation, respectively, decreased with increasing degree of deformation. It was observed that the lower the melting point of the metal studied, the higher the value of k corresponding to a given degree of deformation. (Sci. Abs. 63A:15999, 1960).

2931
Law, J.M. and Richards, W.C. CELL AND THERMOELECTRIC EFFECTS OF TANTALUM ELECTROLYTE CAPACITORS. Electrochem. Soc. J. 109:215-221, Mar. 1962.

A voltage is normally present across the terminals of electrically isolated electrolytic tantalum capacitors. The magnitude, cause, and source impedance of this voltage were investigated. Wet-electrolyte units generate a small, high-impedance, cell emf between the tantalum anode and the silver case. This emf increases with film thickness to a maximum of 3v at elevated temperatures. Solid-electrolyte units generate a small, high-impedance emf, apparently thermoelectrically, normally not exceeding a few millivolts, but on some units, reaching a few hundred millivolts.

2932
Levine, P.H. THERMOELECTRIC PHENOMENA ASSOCIATED WITH ELECTRON-FIELD EMISSION. J. Appl. Phys. 33:582-587, figs., Feb. 1962.

The equilibrium temperature distribution in

an ideal metal rod, one end of which is subjected to an intense electric field, is studied. Particular attention is focused on the case where the emitting end cools down, and the necessary conditions for this effect are derived. Viewed as a "heat pump", the maximum rate of heat flow as a function of emitter temperature is derived, and it is found that rates in excess of 0.1 cal/sec/cm^2 are possible at room temperature if the emitter work function is less than an electron volt.

2933
Lewis, F.A., Orr, J. and Ubbelohde, A.R. CONTACT EFFECTS RESULTING FROM COMPRESSION AND FLASH SINTERING IN GRAPHITE POWDERS. Phys.Soc. Proc. 70B:928-936, Oct. 1957.

Their influence on the thermoelectric power is discussed.

2934
Melehy, M.A. MINORITY CARRIER THERMOELECTRIC COOLING IN p-n JUNCTIONS. Am. Phys. Soc. Bull. 7:88, Jan. 24, 1962.

Abstract only of paper given at 1962 annual meeting of the American Physical Society, January 24, New York.

"The principle of backward injection of minority carriers in p-n junctions is discussed. It is explained that in a forward-biased p-n junction where this type of injection occurs, heat energy is pumped out of the junction causing it to cool off. Some conditions which lead to backward injection of minority carriers are discribed. Theory is developed for a thermoelectric cooling p-n junction structure in which this effect takes place. It is shown that a given dc electrical energy may be used to pump nearly an equal amount of heat energy from one of the junctions to the neighboring ones, provided that the junction temperatures are sufficiently close to each other." Entire item quoted.

2935
Rhoads, E. CHANGE OF LENGTH AND OF THERMOELECTRIC POWER BY MAGNETISATION. Phys. Rev. 15:321-326, Dec. 1902.

A thermopile is constructed of wires in the following complete cycle: iron, alloy, copper, alloy. A great many such cycles being placed in series, alternate ends are heated and cooled by steam and cold-water jackets. The alloy mentioned is of bismuth and antimony and serves to neutralise the thermoelectric effect of the iron and copper junctions so as to give no thermoelectric force on the whole when no magnetic field acts on the system. On placing the whole in a solenoid and passing current, thermoelectric force is produced-which, as the field due to the current increases, first increases to a maximum (M_1), and then diminishes. If the last strong field be reduced gradually, the thermoelectric force increases, attains a maximum (M_2) greater than before, and then, when the field is nil, still remains large. By reversing the field, a complete cycle of a hysteresis nature is obtained. This curve of field and thermoelectric force the author gives, and he shows that it is similar to the curve between field and change of length for the same iron as that used in the experiments above. But the latter curve is not the usual experimental curve; it is obtained by applying the correction for the Maxwell stress $B^2/4\pi$ to the curve. Testing nickel instead of iron the author observes a similar likeness between the two relations. Strain causes a change in thermoelectric power, and so it may be that the strain set up by the magnetisation may produce the changes in thermoelectric force and explain the results. (Sci. Abs. 6:928, 1903).

2936
Shoji, Masakazu. DETERMINATION OF THE IMPURITY CONCENTRATION OF THE p-TYPE RECRYSTALLIZED LAYER BY THERMOELECTRIC POWER MEASUREMENTS. Phys. Soc. Japan. J.;16:2590-2591, Dec. 1961.

In this brief report, the acceptor concentration of the p-type recrystallized layer has been determined by comparing thermoelectric power of the specimen with that of the standard samples.

2937
Shtil'stein, G.M. THERMOELECTRIC PHENOMENA ON THE SUN. Part 1. ELECTROSTATIC FIELD IN THE SOLAR CORONA. Astron. Zhurn. SSSR, 38:463-473, May/June 1961.

In Russian, Trans. in Soviet Astron. 5:344 351, figs., Nov./Dec., 1961.

Possibility of the electrical current emergence in the solar corona due to the

difference in the charges of inequally heated corona regions is considered.

2938
Tyrrell, H.J.V. and Wilson, P.J. INITIAL THERMOELECTRIC POWER MEASUREMENTS ON THERMOCELLS WITH IODINE-IODIDE ELECTRODES AT A MEAN TEMPERATURE OF 30-DEGREES. Chem. Soc. J., no. 12:5390-5396, Dec., 1961.

Thermocells with iodine-iodide electrodes give very reproducible values of initial thermoelectric powers.

2939
Tyrrell, H.J. V. DIFFUSION AND HEAT FLOW IN LIQUIDS. 329p., London, Butterworths, 1961.

Thermoelectric powers of thermocells is a topic discussed on p. 262-271.

2940
Weddell, J.B. THERMOELECTRIC AND ELECTRONVOLTAIC EFFECTS IN A GRADIENT-DOPED SEMICONDUCTOR. Am. Phys. Soc. Bull. 7:89, Jan. 24, 1962.

Abstract only of paper given at the 1962 annual meeting of the American Physical Society, New York, January 24, 1962.

"Let a semiconductor contain concentration gradients of a radioisotope of a constituent element, and of the decay product impurity dopent. The impurity gradient creates quasi-electrostatic forces on excess carriers, due to sloping band edges. Thermodynamic transport equations for electrons, holes, and phonons have been derived. The impurity gradient was assumed to affect the chemical part, and the temperature gradient resulting from the isotope decay energy to affect the electrical part of the electrochemical potential. Analogs of thermoelectric properties have been related to electron-hole-phonon interaction tensors. In the one-dimensional case, the Seebeck coefficient and electrical resistivity are anisotropic, the thermal conductivity is isotropic. The electron-voltaic effect augments the thermoelectric conversion of isotope decay energy to electrical energy. The theory is compared with data obtained with an iron-doped strontium titanate semiconductor containing gradients of strontium 90 and zirconium concentration." Entire item quoted.

2941
Weindler, B. CLASSIFICATION OF METALLIC MATERIALS BY THERMOELECTRIC EFFECTS. Harterei-Tech. Mitt. 16:23-31, Apr. 1961.

In German. Method and apparatus for identification of metals with emphasis on 18/8 and 18/8/2 austenitic stainless and unalloyed low-carbon steel by measurment of thermoelectric potential differences. (Rev. Met. Lit. 18:78, Aug., 1961).

2942
Winckler, G.A.F. and Evans, R.C. THE ISTHMUS EFFECT - A NEW THERMOELECTRIC PHENOMENA. In Power Sources Conference. Proceedings, 15th, 1961, p. 132-134. Red Bank, N.J., PSC Publications Committee, 1961.

"Thermal barriers" are suggested which are constructed from strips of thermoelectric alloy slit transversely until nearly, but not quite, severed. Efficiency measurements are reported of electrical resistance and equilibrium temperature difference between hot and cold junction compared with the same measurements made upon a control couple having no thermal barriers. Electrical resistance was increased 35% while the temperature difference was increased 230% for an approximately constant heat source.

2943
Yumashita, Tadayoshi and Ohta, Tokio. MEASUREMENT OF SEEBECK EFFECT IN PLASTICALLY BENT GERMANIUM. Phys. Soc. Japan. J. 16:1565-1569, Aug. 1961.

Changes of thermoelectric power and electrical resistivity in n- and p-type Ge due to plastic bending are measured at 25-300°C and analyzed theoretically. Value of the dislocation-acceptor level is estimated.

2944
Ziman, J.M. A THEORY OF THE ELECTRICAL PROPERTIES OF LIQUID METALS. I: THE MONOVALENT METALS. Phil. Mag. 6:1013-1034, figs., Aug., 1961.

The thermoelectric power in the solid, and in the liquid, and its change on melting, all follow qualitatively from the form of $\alpha(K)$ and of the scattering cross section for each type of ion.

D. Materials

1. Measurements

2945
Baranskii, P.I. VOLUME-GRADIENT PHENOMENA AND THE LIMITS OF APPLICABILITY OF THE PROBE COMPENSATION METHOD FOR MEASURING THE ELECTRICAL CONDUCTIVITY OF CONDUCTORS. Fiz. Tverdogo Tela 3: 884-888, Mar. 1961.

In Russian. Eng. Transl. in Soviet Phys. - Solid State 3:643-646, Sept., 1961.

The effects considered are: (1) volume Peltier effect; (2) non uniform Joule heating and (3) volume-gradient Thomson effect, in a plastically deformed n-type germanium specimen with a known variation of resistivity along its length.

2946
Birkholz, Ulrich. ON THE EXPERIMENTAL DETERMINATION OF THE THERMOELECTRIC EFFICIENCY OF SEMICONDUCTORS. Solid-State Electron. 1:34-38, Mar. 1960.

In German. The technical use of the thermoelectric effects has been practicable for some years, since the development of special semiconductors. The efficiency of thermoelectric generators, as well as the performance figure of Peltier refrigerators and the figure for reversible heating, are determined by the same material constant, the figure of merit z. This magnitude is obtained by absolute thermoelectric power a, electric conductivity σ and thermal conductivity k according the equation $z=a^2\ \sigma/k$. A method is described by means of which a, σ and k are ascertainable in the range of room temperature by use of a single piece of apparatus; errors of measuring arising by heat radiation, as well as inhomogeneity of the samples, are discussed. (Elec. Eng. Abs. 64:6738, Dec., 1961).

2947
Bobson, Neil. HOT PROBE MEASURES SEMICONDUCTOR THERMOELECTRIC POWER. Electron. 34:61-63, illus., Dec. 8, 1961.

Temperature-stabilized probe determines the thermoelectric power of semiconductor samples without sample preparation or shaping. Permits point measurement of Seebeck coefficient.

2948
Bowley, A.E., Cowles, L.E.J., Williams, G.J. et al. MEASUREMENT OF THE FIGURE OF MERIT OF A THERMOELECTRIC MATERIAL. J. Sci. Instr. 38: 433-435, figs., Nov., 1961.

A description is given of a single piece of apparatus for measuring the three parameters involved in the figure of merit of a thermoelectric material. This apparatus uses only direct current and is based on Harman's technique, in which a temperature gradient is established by means of the Peltier effect. It is demonstrated that the corrections for radiative heat transfer take a relatively simple form at room temperature. It is also shown that the figure of merit of a thermoelectric material can be obtained by measuring the maximum lowering of temperature using the Peltier effect in a junction between the sample under test and a metal.

2949
Bragin, B.K. A NORMAL PLATINUM THERMAL ELECTRODE. Izmeritel. Tekh. no. 7:33-34, Jly. 1960.

In Russian. Transl. in Measurement Tech. no. 7, p. 596-597, Feb., 1961.

Suggests that the utilization of the GNPT (Group of Normal Platinum Electrodes) is an effective and simple method of providing unified thermoelectric testing and will solve several practical problems.

2950
Ginter, J. and Szymanska, W. MEASUREMENTS OF THERMOELECTRIC POWER IN InSb. Acad. Pol. Sci. Bull. Ser. Sci. Math. Astron. et Phys. 9:419-421, 1961.

The experimental method is described and results obtained from measurement of indium antimonide.

2951
Glazov, V.M. and Krestovnikov, A.N. AN INVESTIGATION OF THE THERMOELECTRIC PROPERTIES OF MATERIALS IN MICROVOLUMES. Zavodskaia Lab. 27:416-419, Apr. 1961.

In Russian. Transl. in Indus. Lab. 27: 421-424, figs. Nov., 1961.

Using an apparatus for measuring the thermo-emf in microvolumes in combination

with the optical system of the PMT-3 instrument the micro-emf was measured in the center and at the grain boundaries of germanium-silicon, bismuth-antimony, and copper-chromium-zirconium alloys. The method is suitable for evaluating the degree of liquation microheterogeneity and for studying the reaction of components in ternary alloys.

2952
McNeill, D. J. MEASUREMENT OF THE THERMAL DIFFUSIVITY OF THERMOELECTRIC MATERIALS. J. Appl. Phys. 33:597-600, figs., Feb., 1962.

A simple modification of Angstrom's classical method for the determination of the thermal diffusivity of thermoelectric materials is described. Using the Peltier heat generated at the junction of the specimen and a current lead as a periodic heat source, symmetrical temperature variations may be established in the specimen and the diffusivity derived from the propagation constants of the variations. Results of measurements at room temperature on lead telluride are presented.

2953
Michalski, L. THERMOELECTRIC MEASUREMENTS OF METALLIC SURFACES WITHIN THE RANGE OF 20-200°C. Pomiary 6: 72-76, Feb., 1960.

In Polish. Not examined. (EEAI p. 268, Aug., 1960).

2954
Nettleton, H. R. ON THE MEASUREMENT OF THE THOMSON EFFECT IN WIRES. Phys. Soc. Proc. 29:59-81, 1916-1917.

Describes experimental tests of the relation between thermoelectric power and the Peltier coefficient.

2955
Pinnow, D. A., Li, Che-Yu, and Spencer, C. W. DETERMINATION OF THERMAL DIFFUSIVITY BY UTILIZATION OF THE THERMOELECTRIC EFFECT. J. Sci. Instr. 32: 1417-1418, figs., Dec., 1961.

The purpose of this note is to report a dynamic method for determining thermal diffusivity in thermoelectric materials. In principle, thermal diffusivity can be determined from knowledge of the rate at which a certain established temperature gradient in a thermally isolated specimen returns to the equilibrium temperature. The experimental approach used is similar to that reported by Herinckx and Monfils; however, a simpler analysis is proposed in this note.

2956
Rozhdestvenskaya, T. B. and Teplinskii, A. M. THERMOELECTRIC COMPARATOR FOR MEASURING SMALL ALTERNATING CURRENTS AND CHECKING MICROAMMETERS. Izmeritel. Tekh. p. 41-44, Nov., 1960.

In Russian. Transl., in Meas. Tech. p. 965-969, Nov., 1960.

A description is given of the TEKF-1 thermoelectric comparator, for measuring currents of 20 μA upwards in the range 20 c/s to 200 kc/s with an error not exceeding $\pm$ 5%. (Instr. Abs. 16:7460, 1961).

2. Properties

2957
Alfred University. College of Ceramics, Alfred, N. Y. ANNUAL REPORT. SEMICONDUCTOR MATERIALS, December 1960 - November 1961. 50p., Nov., 1961. (Contract Nonr-1503(01)).

Subjects reported on are: semiconductor materials, Peltier measurements, theory of pulse Peltier cooling, and Hall effect.

2958
Aoki, Masaharu, THERMOELECTRIC COOLING BY BISMUTH-TELLURIDE THERMOJUNCTIONS. I. ELECTRICAL PROPERTIES OF Bi_2Te_3. J. Appl. Phys. (Japan) 28:77-81, Feb., 1959.

Electrical conductivity, Hall coefficient, and thermoelectric power of semiconductive Bi_2Te_3 are measured between 100°K and 650°K. Samples of p-type Bi_2Te_3 and n-type Bi_2Te_3(Te excess) are partially degenerated within the present temperature range, so it is necessary to apply Fermi-Dirac statistics for the interpretation of the experimental results. The Hall mobility parallel to the cleavage plane varies with T^{-2} for holes. The energy gap is E_o= 0.23 ev at 0°K. The effective masses are m_n= 1.03 m for electrons and m_p=1.24 m for holes. The mobility ratio is about b= 1.7. The Hall mobility for electrons in polycrystalline n-type Bi_2Te_3 (Te excess) varies as $T^{-5/2}$. (Japan Sci. Rev. Mech. & Elec. 6:79, 1959).

2959

Aoki, Masaharu and Suge, Yoshio. THERMOELECTRIC COOLING BY BISMUTH TELLURIDE THERMOJUNCTIONS. 5. PURIFICATION OF THERMOELECTRIC MATERIALS. J. Appl. Phys. (Japan) 29: 363-370; June 1960.

Alkali treatment and zone melting are found efficient to remove Cu, Ag and Pb in Bi, and vacuum distillation for removing Cu, Ag and Pb in Te. Pure Bi_2Te_3 thus prepared has thermoelectric power α = 235 μV/deg. and resistivity $\rho = 1.16 \times 10^{-3}$ ohm-cm. The influence of additive impurities on Bi_2Te_3 is examined. Tl, Li, Pb and Cd etc. give P-type and Cu, Ag, Se, Te, halogen and metal-halides etc. give N-type impurities. Thermoelectric properties are examined of PbTe, Sb_2Te_3, Bi_2Te_3-Sb_2Te_3 and Bi_2Te_3-Bi_2Se_3 solid solutions. The result shows that the solid solution of isomorphous compounds is suitable for thermoelectric material. With $(Bi-Sb)_2Te_3$ P-type element and $Bi_2(Te-Se)_3$ N-type element thermojunctions, the temperature drop of 71.3 deg was attained with hot junction of 30°C. (Japan Sci. Rev. Mech. & Elec. 7:1238, Aug., 1960).

2960

Aoki, Masaharu and Chang, Z. P. THERMOELECTRIC COOLING BY BISMUTH-TELLURIDE THERMOJUNCTIONS. II. THERMAL CONDUCTIVITY OF Bi_2Te_3. (J. Appl. Phys. (Japan) 28:82-84, Feb., 1959.

Thermal conductivity of semiconductive Bi_2Te_3 is measured between 100°K and 400°K. The lattice component of thermal conductivity k_l parallel to the cleavage plane of Bi_2Te_3 varies in inverse proportion with absolute temperature, i.e., $k_l = 6.8 \times 10^{-2}/T$ watt/cm.deg. Electrical and thermal conductivities and thermoelectric power of Bi_2Te_3-Bi_2Se_3 system are also measured at room temperature. The minimum of the thermal conductivity lies at the composition $3Bi_2Te_3$. (Japan Sci. Rev. Mech. & Elec. 6:79, 1959).

2961

Arizona State University, Tempe, Ariz. RESEARCH TO PRODUCE A TEMPERATURE STABLE MATERIAL WITH A HIGH THERMOELECTRIC FIGURE OF MERIT, by H. B. Whitehurst, L. H. Stubbs, and J. J. Morrison. 17p., Aug. 17, 1961. (Quart. Prog. Rept. 7) (Contract DA36-039-sc-85249) (AD-264 253).

Samples of high density polycrystalline rutile have been prepared. These samples, in the form of small slices with one polished face, were partially reduced to form semiconductors. Thin films of TiO_2 coprecipitated with other metal oxides, have been deposited on the polished surfaces. Samples made in this way show rectifying properties. Diodes have been made which have a reverse breakdown voltage of more than fifty volts and very small inverse currents. The thermal stability of rectifiers, with the exception of those which contain vanadium oxide in the barrier layer, is adequate at 500°C, but at 600°C the semiconductor oxidizes in air. Ternary oxide systems of the type Ti sub n X sub n-1 02 are being prepared, where x represents a metallic ion which can be substituted for Ti in the rutile crystal lattice. The method of preparation is the same as that which has been used to form the polycrystalline rutile semiconductors.

2962

Aronson, S., Rulli, J. E. and Schaner, B. E. ELECTRICAL PROPERTIES OF NONSTOICHIOMETRIC URANIUM DIOXIDE. J. Chem. Phys. 35:1382-1388, Oct., 1961.

Electrical conductivity and thermoelectric power measurements were made on nonstoichiometric UO_2 at temperatures of 500° - 1150°C. An approximate equation for the thermoelectric power Q, is $Q = k/e \ln(1-2x/2x)$.

2963

Atoyan, A. T. THERMOELECTRIC PARAMETERS OF A SYNTHETIC SEMICONDUCTOR BASED ON CUPROUS SULFIDE. Trudy 1-oi Mezhvuzovsk. Konf. po Sovremen. Tekh. Dielektrikov i Poluprovodnikov, Leningrad. 1956, p. 325-329, 1957.

In Russian. Abs. in Chem. Abs. 55:16173, 1961.

2964

Blakemore, J. S. DESIGN OF GERMANIUM FOR THERMOMETRIC APPLICATIONS. Rev. Sci. Instr. 33: 106-112, figs., Jan., 1962.

Germanium doped with certain impurities has a strongly temperature-dependent conductivity below the liquid air range,

suitable for use in secondary thermometry. Two mechanisms are responsible for this behavior: (1) down to about 10°Km the conduction is provided by free current carriers (electrons or holes) liberated from impurity atoms. (2) control of the conductivity below 10°K is exercised by the relatively feeble "impurity conduction" process. For both processes, conductivity depends not only on the primary doping atoms but also on the density of compensating impurities; indeed, low temperature impurity conduction can be inhibited unless some compensating centers are present. In order that germanium thermometers should have resistance temperature characteristics which "scale" reasonably well from one unit to another, it is desirable to deliberately incorporate a number of compensators, sufficient to suppress any influence of uninvited impurities. Moreover, by control of both the primary and compensating impurity densities, a resistance-temperature characteristic can be controlled to emphasize a desired range. The transition between free carrier conduction and impurity conduction is relatively sharp for some impurities (e.g. gallium) but occurs over a wide range of temperature for other impurities (e.g., arsenic). This influences the suitability for thermometry in various ranges. Characteristics of wide range and narrow range thermometer materials are illustrated.

2965

Born, H. J., Legvold, Sam, and Spedding, F. H. LOW-TEMPERATURE THERMOELECTRIC POWER OF THE RARE-EARTH METALS. J. Appl. Phys. 32:2543-2549, figs., Dec. 1961.

The Seebeck coefficients (thermoelectric powers) of yttrium, lanthanum, and 11 of the rare earths have been measured for the temperature range 7 to 300°K. The transitions reported by other investigators on specific heat, magnetic moment, and resistivity at the magnetic ordering temperatures are, in many instances, visible also in the curves of thermoelectric power (TEP) vs temperature. The Neel temperature is evidenced by a change in slope of the TEP vs T curve. The ferro-antiferro transition temperature is obvious only in the case of dysprosium and appears as a sharp drop in the curve. With the exception of samarium and ytterbium, the TEP's of the metals are negative throughout most of the temperature range covered, and, with the exceptions, the TEP curves have about the same slope near room temperature. Also cited as PhD thesis, Iowa State University. (see entry 806).

2966

Braun, Horst and Sedlatschek, Karl. RECENT INVESTIGATIONS OF HIGH-TEMPERATURE ALLOYS OF MOLYBDENUM AND TUNGSTEN WITH TRANSITION METALS OF GROUPS IV_A - VII_A OF THE PERIODIC TABLE. In International Powder Metallurgy Conference, New York, 1960, p. 645-659, New York, Interscience, 1961.

Thermoelectric power was one of the properties studied.

2967

Burdiyan, I., Kozneritsa, Ya., and Stepanov, G.I. THERMOELECTRIC PROPERTIES OF SOLID SOLUTIONS OF THE ALUMINUM ANTIMONIDE-GALLIUM ANTIMONIDE SYSTEM. Fiz. Tverdogo Tela 3: 1879-1882, 1961.

In Russian. Transl. in Soviet Phys. Solid State 3: 1368-1370, Dec., 1961.

This paper is devoted to an investigation of the thermoelectric properties of solid solutions of the AlSb-GaSb system in the temperature range from 120 to 900°K. The following compositions were studied: 3AlSb-GaSb, AlSb-GaSb, 2AlSb, 3GaSb, AlSb, 4GaSb and GaSb. The samples were all p-type. The values of hole effective masses were calculated on the assumption that carriers are scattered by acoustic lattice vibrations and by the nonperiodicity of the alloy structure.

2968

Busch, G., and others. STRUCTURE, ELECTRICAL, AND THERMOELECTRIC PROPERTIES OF STANNIC SELENIDE. Helv. Phys. Acta 34: 359-368, 1961.

In German. Single crystals of the semiconducting compound $SnSe_2$ were prepared by sublimation and by the Bridgman technique. X-ray analysis showed the structure of the undeformed compound to be of the CdI_2 type with a = w. 811 A, C = 6.137A. Resistivity and Hall effect measurements lead to an energy gap of 1 eV. Investigations of the Seebeck effect and thermal conductivity were carried out in the range 240 to 370°K. Energy flux by radiation through the crystal was found to enhance the

thermal conductivity appreciably. (Sci. Abs. 64B:13375, 1961).

2969
Carlton, R. D. THERMOELECTRIC MATERIALS TODAY. Mat. Design Eng. 55:79-82, illus., Jan., 1962.

New and improved materials (lead telluride, germanium telluride, cesium sulfide and bismuth telluride are mentioned) are bringing thermoelectric devices closer to commercial reality. Properties, materials comparison, performance measurement, processing methods and current uses are among the topics discussed.

2970
Chrysler Corp. Engineering Division, Detroit, Mich.
RESEARCH PROGRAM ON SEMICONDUCTING COMPOUNDS FOR THERMOELECTRIC POWER GENERATION AT HIGH TEMPERATURES. Final Report. 7p., figs. Aug., 1961. (Contract Nobs-78664) (AD-265950).

No promising high temperature thermoelectric materials were discovered, although an analysis under certain plausible assumptions indicates that a figure of merit of approximately 0.6×10^{-3} could be obtained with more refined methods of preparation.

2971
Cornell University. Baker Laboratory of Chemistry, Ithaca, N.Y.
CARRIER CHARACTERISTICS IN COPPER-DOPED WO_3 FROM CONDUCTIVITY, HALL VOLTAGE, AND THERMAL e.m.f. STUDIES, by M.J. Sienko and P.F. Weller. 25p., n.d. (AFOSR-1705) (Contract AF 49(638)191).

Solid state studies of Cu_xWO_3 including precise Hall voltage determination and thermoelectric power studies, have been undertaken in order to identify the nature of the carriers, their concentration, and their mobility.

2972
Digdale, J.S. and Mundy, J.N. THE PRESSURE DEPENDENCE OF THE THERMOELECTRIC POWER OF THE ALKALI METALS AT ROOM TEMPERATURE. Phil. Mag. 6: 1463-1473, Dec., 1961.

The thermoelectric power S of the alkali metals has been measured under pressures up to 3000 atmospheres at room temperature. A pressure of about 400 atmospheres causes S to change sign in caesium. The results are discussed in terms of the distortion of the Fermi surface under pressure. A relationship between S and the pressure coefficient of electrical resistivity is noted.

2973
Dudkin, L.D. and Abrikosov, N.Kh. PROBLEMS OF ALLOYING SEMICONDUCTING ALLOYS. Symposium: "Vopr. Metallurg. i Fiz. Poluprovodnikov", Akad. Nauk. SSSR, Moscow, p. 94-106, 1959.

In Russian. The conditions determining the solubility of substitutional impurities were investigated using the semiconducting compound $CoSb_3$ as the example. Since the nature of the effect of sol. impurities on the properties of semiconductors is determined by the change in the number and sign of current carriers and by the deg. of scattering of electron and phonon waves, the thermoelectric properties, their dependence on temp. and the thermal conductivity of alloyed metals were investigated and compared with $CoSb_3$ cpd. without impurities in order to assess the solubility. (Abs. J. Metallurg. nos. 5/6A:12, 1961).

2974
DuPont de Nemours, E.I., and Co., Wilmington, Del.
THERMOELECTRIC PROPERTIES OF SELENIDES AND TELLURIDES OF GROUPS VB AND VIB METALS AND THEIR SOLID SOLUTIONS, by W.T. Hicks and J.T. Looby. 40p., Oct. 10, 1961. (Quart. Rept. 1) (Contract Nobs-84824) (AD-266 003).

In a study of the $MoSe_2$-$NbSe_2$ system, the effects of sintering conditions and of deviations from stoichiometry on resistivity, Seebeck coefficient and density were investigated for the pure compounds and for the 1:1 solid solution. The data reported at this time are limited mostly to room-temperature measurements and, therefore, of no immediate practical value, since the thermoelectric figure of merit for these materials is poor at temperatures below 400 C. Concurrent work on the construction of a thermoelectric generator for efficiency and life tests dealt with junction fabrication problems on tungsten selenide. Ultrasonic soldering provides an excellent cold junction, while powered iron, sintered

under pressure, promises to provide a satisfactory bonding layer between the selenide and an iron connector plate on the hot side.

2975
ELECTRONIC MATERIALS, NOW AND IN THE FUTURE. Electron. Indus. 20:151-166, Dec. 1961.

A few paragraphs on thermoelectric materials are included.

2976
Electro-Optical Systems, Inc., Pasadena, Calif.
HIGH TEMPERATURE SEMICONDUCTING COMPOUNDS FOR THERMOELECTRIC POWER GENERATION, by C. Leung, C.B. Jordan, et al. 5 issues, 1961, 1962. (Repts. 1592-2M, -1, -2, -3, -4, -5, and Final) (Bimon. Prog. Repts. 1 through 5 and Final) (Contract Nobs-84327)

Synthesis, thermoelectric properties and potential usefulness are reported for certain sulfides, selenides, and tellurides of uranium and thorium.

2977
Feltin'sh, I. A. SEMICONDUCTORS AND THEIR APPLICATIONS IN ELECTRICAL ENGINEERING. I. NEW SEMICONDUCTOR MATERIALS -- SOLID SOLUTIONS OF $GaAs$-Ga_2Se_3. Trudy Inst. Energet. i Elektrotekh. Akad. Nauk. Latv. SSR. no. 11, p. 5-16, 1961.

In Russian. Specimens of different compositions belonging to the system $GaAs$-Ga_2Se_3 were made, and examined by X-ray and micrographic techniques. It was found that the ZnS structure was maintained throughout the complete range of solid solutions, and values of density and microhardness are given. Comprehensive electrical measurements were also made. The dependence of electrical conductivity on temperature is given for various compositions and resistivities. Hall constant forbidden energy gap and the variation of number of carriers with temperature was also investigated. It is concluded that for compositions close to GaAs the electron gas is strongly degenerate. (Sci. Abs. 64A (Pt. II): 19877, Dec., 1961.

2978
Fleischmann, H. THERMAL CONDUCTIVITY, THERMOELECTRICITY AND ELECTRICAL CONDUCTIVITY OF SEMICONDUCTING SOLID SOLUTIONS OF TYPE $(A^{I}_{x/2} B^{IV}_{1-x} C^{V}_{x/2} D^{VI})$. Z. Naturforsch. 16A: 765-780, Aug., 1961.

In German. A large number of experimental results are reported. The main conclusions are that the thermal conductivity of mixed crystals $(Ag_{x\ 2x}Pb_{1-x}Sb$ (or $Bi)_{x\ 2x})Te$ is very low; the thermoelectric effectiveness $Z = a^2c/k_{total}$ (a = T.E.P.; c = electrical, k = thermal conductivity, can reach 0.003 degree^{-1}; the energy gap for x = 0.8 is 0.6 eV; and the effective mass ratio $m_e m_h$ is large. (Sci. Abs. 64A(Pt. II): 19868, Dec., 1961).

2979
France. Compagnie General de Telegraphie San Fil, Puteaux, Seine.
PREPARATION AND PROPERTIES OF THERMOELECTRIC MATERIALS. Final Report, August 1, 1960 - September 30, 1961. 22p., Sept. 30, 1961. (Contract DA91-591-EUC-1505) (AD-265121)

Research on methods of preparation of molybdenum and tungsten tellurides and determination of some of their fundamental properties.

2980
France. Laboratoire Central Des Industries Electriques, Fontenay-aux-Roses.
THE ELECTRICAL BEHAVIOUR OF CADMIUM ARSENIDE, by N. Sexer. 7p., n.d.

The properties of the charge carriers in cadmium arsenide were studied by means of electrical conductivity, Hall effect and Seebeck effect measurements.

2981
France. Laboratoire Central Des Industries Electriques, Fontenay-aux-Roses.
RESEARCH ON THERMOMAGNETO-ELECTRIC EFFECTS IN SEMICONDUCTOR, Final Report, by P. Aigran. 9p., 1960. (AFCRC-TR-59-293) (Contract AF61(052) 138) (AD-243 488) (PB 152 199).

An attempt was made to determine whether a study of thermomagnetoelectric effects, in combination with magnetoconductance effects could be used to investigate the band structure of semiconductors. Samples of n- and p- type Mg_2Sn were prepared by varying the rate of crystal growth from the melt; n- and p-type crystals were produced

by growth rates of 75 and 150° C/hr, respectively. The ingots were either single crystals or large-grain polycrystals. Single crystal-oriented specimens were cut from these; the orientation was carried out with an X-ray diffractometer. Magneto-conductance measurements on p-type Mg_2Sn at 77°K yielded values of 910^{-2} ohm/cm and 200 cc/coul for o_o and p_A, respectively. These observations, together with thermoelectric power measurements indicated that the top of the valence band is probably made up of a single isotropic valley with an effective mass of $(0.14 \pm 0.03)m_o$. The bipolar Nernst effect of Mg_2Sn was large enough to indicate that both Mg_2Sn and Mg_2Pb have potential value as heat detectors. (Res. Repts. 35: 794, 1961).

2982

Frederikse, H. P. R., Hosler, W. R. and Becker, J. H. ELECTRONIC CONDUCTION IN RUTILE(TiO_2). In International Conference on Semiconductor Physics, Prague, 1960. Proceedings, p. 868-871, New York, Academic Press, 1961.

Measurements of conductivity, Hall effect and thermoelectric power performed on slightly reduced crystals of rutile can be explained with a model involving two conduction mechanisms; one of free electrons in a narrow 3d-band of titanium(above 5°K) and the other of self-trapped electrons or polarons in a polaron band (below 5°K). The ionozation energy of the polaron increases from 0.01 to 0.07 eV with increasing temperature.

2983

General Atomic. John Jay Hopkins Laboratory for Pure and Applied Science, San Diego, Calif.
HIGH-TEMPERATURE BROADBAND SEMICONDUCTORS, April 1-June 30, 1961, by P. H. Miller, Jr. 12p., Aug. 16, 1962. (GACD-2495) (Contract NObs-77144) (AD-266021)

Work done on the study and development of new semiconductor materials for thermoelectric generation at temperatures about 800°K is summarized. Graphs are presented for the thermoelectric properties of barium-doped and undoped cerium sulfide and of praseodymium sulfide. Work on p-type materials and electronic processes in rare earth sulfides is described. (Nuclear Sci. Abs. 16:10185, May 15, 1962).

2984

General Ceramics, Co., Keasbey, N. J.
OXIDE THERMOELECTRIC MATERIALS. 4 issues, 1960, 1961. (Bimon. Prog. Repts. 4, 5, 6, and Final) (Contract Nobs-78414).

Research was continued on Seebeck coefficient and dc resistivity measurements of oxide thermoelectric materials. Raw materials investigated were (1) zinc oxide, (2) alumina, (3) tin oxide, (4) antinionic oxide, (5) titanium dioxide, (6) vanadium pentoxide, and (7) indium oxide. It was concluded that the formation of mixed-valency oxide semiconductors proved to be a practical approach for obtaining low-resistivity compositions. The most promising materials developed for thermoelectric use were the compositions of the $(Al_2O_3)_x(ZnO)_{100-x}$ series, all n-type, "x" ranging from 0 to 6.

2985

General Electric Co., Syracuse, N. Y.
MATERIALS RESEARCH AND DEVELOPMENT FOR THERMOELECTRIC POWER GENERATION. 5p., Sept. 25, 1961. (Tech. Prog. Rept. 15) (Contract DA44-117-TC-639).

Room temperature measurements on a sample of $AgGaTe_{2.04}$ are given; room temperature and high temperature measurements on two copper-doped $CuGaTe_2$ samples are given.

2986

General Electric Co. Aircraft Accessory Turbine Dept., Lynn, Mass.
OPTIMIZATION OF THERMOELECTRIC ENERGY CONVERTERS. 53p., Feb. 14, 1961. (Bimon. Prog. Rept. 5) (Contract Nobs-78403) (AD-265857).

This is a report on thermal systems studies; encapsulation of thermoelectric materials; study of I_3V, II_3V_2, and I-II-V compounds; increasing of band-gaps of high melting materials; and study of II-IV compounds.

2987

Goff, J. F. and Pearlman, N. THE LOW TEMPERATURE ASPECT OF THE THERMAL CONDUCTIVITY AND THE THERMOELECTRIC POWER OF n-TYPE GERMANIUM. In International Conference on Low Temperature Physics, Proceedings, 7th, p. 284-288, Canada, University of Toronto Press, 1961.

Effects of temperature, impurity concentration and electron-impurity conduction on the thermal conductivity of single crystal specimens doped with Sb, As, and SbGa impurities are measured from 2-77°K. (Rev. Met. Lit. 18:52, Aug. 1961).

2988
Goldsmid, H.J. and Delves, R.T. MATERIALS FOR THERMOELECTRIC REFRIGERATION. Gen. Elec. Co. J., 28:102-105, 1961.

Some thermoelectric materials and their properties are discussed.

2989
Goldsmid, H.J. EFFECTS OF IMPURITIES IN BISMUTH TELLURIDE. In International Conference on Semiconductor Physics, Prague, 1960. Proceedings, p.1015-1017, New York, Academic Press, 1961.

Experiments on Bi_2Te_3 containing different impurities are reported. Thermoelectric measurements in the intrinsic range, on solid solutions of Bi_2Te_3 with Sb_2Te_3 show that the mobility of electrons can exceed that of holes over a wide range of compositions.

2990
Goletskaya, A.D., Kutasov, V.A., and Popova, E.A. PRODUCTION AND INVESTIGATION OF THERMOELECTRIC MATERIALS ON THE Bi-Sb-Te BASIS. Fiz. Tverdogo Tela 3:3002-3008, Oct. 1961.

In Russian. Transl. in Soviet Phys. Solid State 3:2189-2193, Apr. 1962.

Specimens of n-type Bi_2Te_3 and of p-type solid solution consisting of 75% Sb_2Te_3 + 25% Bi_2Te_3, with maximum efficiencies of $2.4 \cdot 10^{-3}$ and $3 \cdot 10^{-3}$ deg^{-1}, respectively, have been produced by controlled crystallization. The maximum temperature difference ΔT_{max} attained by a thermocouple made from these materials reaches 70°C (with a hot junction temperature of + 30°C).

2991
Grechanik, L.A., Petrovykh, N.V. and Karpechenko, V.G. PREPARATION AND PROPERTIES OF GLASSY OXIDE SEMICONDUCTORS OF THE $VO_{2.5}$-$PO_{2.5}$-RO_x TYPE. Fiz. Tverdogo Tela 2:2131-2139, Sept. 1960.
In Russian. Transl. in Soviet Phys. Solid State 2:1908-1915, Mar. 1961.

Reports a study of semiconducting $VO_{2.5}$-$PO_{2.5}$-RO_x glasses.

2992
Hach, R.J., Brau, M.J., and Burkhalter, T.S. CONTINUOUS CASTING OF THERMOELECTRIC MATERIALS. J. Sci. Instr. 32: 1341-1343, figs., Dec. 1961.

A continuous casting apparatus has been developed that will produce thermoelectric material rapidly, reliably, and in large quantities with a minimum amount of labor. Bismuth telluride and alloys of Bi_2Te_3, Sb_2Te_3, and Bi_2Se_3 were cast in rods up to 70 in. in length. The deviation of the thermoelectric properties throughout the length of the rods was less than 5%.

2993
Hashimoto, Kimio. GALVANOMAGNETIC EFFECTS IN BISMUTH SELENIDE Bi_2Se_3. Phys. Soc. Japan. J., 16:1970-1979, Oct. 1961.

Measurement of constant energy surface shapes, principal effective mass ratios, Hall coefficient and thermoelectric power on single crystal specimens of Bi_2Se_3 at 90°K.

2994
Heller, M.W. and Danielson, G.C. ELECTRICAL PROPERTIES OF Mg_2Si SINGLE CRYSTALS. In International Conference on Semiconductor Physics, Prague, 1960. Proceedings, p.881-884. New York, Academic Press, 1961.

The Seebeck coefficients (thermoelectric power) for both n-type and p-type Mg_2Si single crystals were measured from 7 to 1000°K. At low temperatures the magnitude of the Seebeck coefficient showed a pronounced maximum which is interpreted in terms of the phonon drag effect. At high temperatures (intrinsic range) the Seebeck coefficient varied inversely as the absolute temperature. New electrical resistivity and Hall coefficient data were also obtained.

2995
Horizons, Inc., Cleveland, Ohio. RESEARCH IN ELECTRICAL PROPERTIES OF INTERMETALLIC COMPOUNDS, by T.S. Liu and R. Bobone. 41p., illus., Jly. 22, 1954. (Final Rept.) (AFOSR-TR-54-20) (Contract AF18(600)774) (AD-40535).

Research concerned with the preparation

and electrical measurements on Ni-Al alloys and Ni-Al-Cu ternary alloys in the cubic β region. The measurements show that the locus of minima of the resistivity for the Ni-Al-Cu ternaries is to be found within a strip containing the transition line from nondefect to defect structures. Measurements of resistivity and thermoelectric power vs temperature are given. A qualitative explanation of the main features in the electrical behavior of the above alloys, based on the Brillioun zone theory, is included.

2996
Iowa State College. Ames Laboratory, Ames, Iowa.
SEEBECK EFFECT IN MAGNESIUM SILICIDE, by M.W. Heller, and G.C. Danielson. 113p., Nov.1960. (Rept.IS-266) (Contract W-7405-eng-82).

The Seebeck coefficient (thermoelectric power) was measured from 7 to 1000°K for both n-type and p-type single crystals of Mg_2Si. The room temperature carrier concentrations were as low as 3×10^{18} cm^{-3} for the silver-doped, p-type samples. At low temperatures, the magnitude of the Seebeck coefficient showed a pronounced maximum which is interpreted in terms of the phonon drag effect.

2997
Kentucky University. Research Foundation, Lexington, Ky.
ELECTRICAL OPTICAL AND THERMAL PROPERTIES OF THE $M_2{}^{Vb}N_2{}^{Vlb}$ SEMICONDUCTORS, Final Report. 129p., Oct.1961. (AFOSR-TR-60-124)

Thermoelectric studies are reported, p.85-99.

2998
Kjekshus, A. and Pearson, W.B. THERMOELECTRICITY AND ELECTRICAL RESISTIVITY OF DILUTE COPPER ALLOYS OF CHROMIUM, MANGANESE, IRON, AND COBALT AT LOW TEMPERATURES. Can.J.Phys.; 40:98-112, figs., Jan., 1962.

Low-temperature thermoelectric and electrical resistivity measurements on dilute copper alloys with Cr, Mn, Fe, or Co are reported and discussed, particularly in relation to similar measurements on gold alloys. This paper is a sequel to an earlier paper where the thermoelectric power of "pure" copper was analyzed.

2999
Kamigaichi, Takahiko. ELECTRICAL AND MAGNETIC PROPERTIES OF CHROMIUM SULFIDES. Hiroshima Univ.J.Sci. 24A. 371-388, 1960.

The electrical conductivity σ, thermoelectric power α, and magnetic susceptibility x of CrS_x with $0.95 \leq x \leq 1.20$ were measured from 77 to 800°K. For $0.95 \leq x \leq 1.12$ the specimens are semiconductors at room temperature but an anomaly in σ and α at 350° indicates a transition from CrS + Cr_7S_8 (of NiAs structure) to the pure NiAs structure. For $1.13 \leq x \leq 1.20$ (the specimens are metallic with negative α. CrS and NiAs-type Cr_7S_8 are antiferromagnetic substances with Neel temperatures of 180 and ~140°C respectively. For $x \gtrsim 1.17$, the specimens are ferrimagnetic. (Sci.Abs.64B:14465, Nov., 1961).

3000
Kolomoets, N.V. and Vedernikov, M.V. THERMOELECTRIC PROPERTIES OF FERROMAGNETIC METALS AND THEIR ALLOYS. Fiz.Tverdogo Tela 3:2735-2745, Sept., 1961.

In Russian. Transl.in Soviet Phys.Solid State 3:1996-2003, Mar.1962.

An experimental investigation is performed of the thermal emf as a function of composition for the alloy systems Ni-Co, Ni-Fe, Ni-Mn, and Co-Fe at room temperature and as a function of temperature in the range 20 to 1200°C. An approximate theoretical formula is given for the thermal emf. and a qualitative explanation is given for the dependence of the thermal emf on the band structure of the metal. On the basis of this relationship, the band diagrams are plotted from experimental values for the metals Fe, Co, and Ni; these diagrams permit a satisfactory explanation of both the thermoelectric and magnetic properties of these metals. The concepts developed concerning the relationship between the thermoelectric properties and the band structure make it possible to achieve a common approach in studying the properties of various alloys of metals belonging to the 3d-transition series.

3001
Kopec, Z. DENSITY OF STATES, EFFECTIVE MASS OF ELECTRONS IN InSb. Acad. Pol. Sci. Bull. Ser. Sci. Math. Astron.

et Phys. 8:105-109, 1960.

Measurements have been made of the thermoelectric e.m.f., conductivity and Hall coefficient of InSb samples with electron concentrations from 2×10^{14} cm^{-3} to 9×10^{18} cm^{-3}, at temperatures from 125 to 500°K. The "classical" concept of a constant effective mass for all carriers is found to be invalid, since InSb exhibits considerable divergencies from the quadratic dispersion law. In analysing the results the effective mass is taken as a variable coefficient depending on the dispersion law and on the kind of phenomenon being considered. These coefficients vary with the carrier concentration and the temperature. Results of the variation of effective mass on carrier concentration, obtained from the observations, are compared with the theoretical predictions based on various scattering mechanisms and a dispersion formula for the InSb conductivity band. (Sci. Abs. 64A:1074, 1961).

3002

Korshunov, V.A. and Gel'd, P.V. ELECTRIC CONDUCTIVITY AND THERMOELECTROMOTIVE FORCE OF MANGANESE-SILICON ALLOYS. I. TECHNICAL ALLOYS CONTAINING Mn_3Si and Mn_5Si_3. Izvest. Vysshikh Ucheb. Zaved. Fiz. no. 6, p. 29-34, 1960.

In Russian. Results are given of measurements of the electrical conductivity (20-1350°) and of the differential thermo-e.m.f. (20-700°) of commercial Mn alloys with Si, containing Mn_3Si and Mn_5Si_3. The electrical conductivity of the investigated alloys has a min. at temp. ~500°, changing at lower temp. according to the law for metals and at higher temp. according to the law for metals and at higher temp. according to the law for semiconductors. The semiconducting nature of the dependence of the electrical conductivity on temp. is preserved in the liq. state. It is assumed that the electron gas of the current carriers is degenerate at room temp. (Abs. J. Metallurgy nos. 5/6A:41, 1961).

3003

Kurov, G.A. and Pinsker, Z.G. A STUDY OF THIN LAYERS OF CHANGING COMPOSITION IN THE SYSTEM INDIUM-ANTIMONY. Zhurn. Tekh. Fiz. 28:29-34, 1958.

In Russian. Transl. in Soviet Phys. Tech. Phys., 3:29-34, Jan., 1958.

Layers 1-6 μ thick were obtained by simultaneous evaporation under vacuum from independent sources of In and Sb onto glass strips at room temperature. Due to the geometrical arrangement of sources and strip, the chemical composition of the deposit along a strip changed. The thermoelectric force α and the electrical resistance R were measured at various points along the strip before and after a 2-hr anneal at ~110°C. Electron diffraction photographs are presented; they show the presence of amorphous Sb at the Sb-rich ends of the strips, hexagonal and cubic InSb at the centers, and metallic In at the other ends. Both α and R had maxima at the composition InSb. For the InSb portions the weak temperature dependence of R(80-420°K) indicated that the material was extrinsic at these temperatures. The Hall mobility of holes in the layers (which were all p-type) was low (~ 8 cm^{2}v^{-1}sec^{-1}).

3004

Lainer, D.I. and Golubtsov, L.M. WAYS OF INCREASING THE THERMOELECTRIC PROPERTIES OF THE SEMICONDUCTOR ZINC-ANTIMONY ALLOY. Tsvet. Met. 34:69-74, Feb., 1961.

In Russian. Transl. in Tsvetnye Metal. The Soviet Journal of Non-Ferrous Metals 2:72-76, Feb., 1961.

Effect of Ag, Cd, In, Sn, Te, Bi, Pb, Cu, Si, Ge, Al, and Fe present in quantities up to 1.50% in a Sb-Zn alloy containing 35% Zn on thermoelectric effect and conductivity, microstructure and phase diagrams. (Rev. Met. Lit. 18:33, Sept. 1961 & Abs. J. Metallurgy nos. 5/6A:5, 1961).

3005

Lashkaryov, G.V. and Samsonov, G.V. CHARACTERISTICS OF REFRACTORY COMPOUNDS OF TRANSIENT METALS AS MATERIAL FOR THERMOELECTRIC TRANSFORMERS. Akad. Nauk. Ukrain. RSR. Dopovidi. p. 1148-1151, 1961.

In Russian. Presents results of calculations of the quality factors and the corresponding efficiencies of refractory compounds of transition metals. It is possible to employ silicides of Mn, Re, and Cr (efficiency up to 13%), and CrN (efficiency 2%) as materials for thermo-

electric generators. (Battelle Tech. Rev. 11:659, Jan. 1962).

3006
Lücke, K. STUDIES OF THE RECOVERY OF ELECTRICAL RESISTANCE AND THERMOELECTRIC FORCE OF COMMERCIAL COPPER WIRES. Z. Metallk. 42:1-10, 1951.

A study was made of alterations in electrical properties (as a measure of recovery) of hard-drawn, commercial Cu wires, giving varying degrees of reduction, on annealing for periods up to 2500 min. at 100-180°. (Brit. Abs. B1:1683, Dec. 1952).

3007
MacDonald, D. K. C., Pearson, W. B. and Templeton, I. M. THERMOELECTRICITY AT LOW TEMPERATURE. IX. THE TRANSITION METALS AS SOLUTE AND SOLVENT. Roy. Soc. London Proc. 266:161-183, figs., Mar. 6, 1962.

Transition metals (in particular Cr, Mn, Fe, Co, and Ni) present as solutes give rise to highly anomalous thermoelectric powers and unusual resistive behavior at very low temperatures. Following an outline of the theories which have been proposed to account for this behavior, experimental data are presented on alloys of gold as parent metal with transition element solutes down to very low temperatures, and the results compared broadly with the conclusions of present theory. It is generally believed that the fundamental origin of the anomalous thermoelectric behavior lies in the spin-dependent scattering of conduction electrons by the magnetic solute ions.

Experimental data are also presented of the thermoelectric behavior down to very low temperatures of alloys of the transition metals Pd and Pt with both transition elements and non-transition elements as solutes.

3008
MacDonald, D. K. C., Pearson, W. B. and Templeton, I. M. THERMOELECTRICITY OF LITHIUM ALLOYS AT VERY LOW TEMPERATURES. Phil. Mag. 6:1431-1437, Dec. 1961.

As lithium is apparently the only alkali metal which will take heterovalent impurities into solid solution, alloys with Mg, In and Al were prepared and their absolute thermoelectric power examined in the temperature range from about 0.1° to 1.2°K. It was found that the change of diffusion thermoelectric power of Li on alloying is in many ways surprising, and there is a discussion as to whether the observed behavior may reasonably be attributed to the influence of conduction electron scattering or to a change in the electron density of states of lithium.

3009
Massachusetts Institute of Technology. Dept. of Electrical Engineering, Cambridge, Mass. THEORETICAL AND EXPERIMENTAL RESEARCH ON THERMOELECTRICITY. January 15-July 15, 1961. 104p., Jly. 15, 1961. (AFCRL 763) (Sci. Rept. 5) (Contract AF19(604)-4153) (AD-264491)

Materials research has continued in the examination of the II-VI, IV-VI and V-VI compound systems and several types of semiconductor devices have been investigated.

A new method of determining the carrier effective mass from infrared reflections have been developed in connection with the investigation of the anomalous thermal conductivity and electronic properties of PbTe. Electrical characteristics of indium-doped p-n junctions in CdTe are described. Use of p-n junctions as photovoltaic converters with high photon densities produced by a thermal source in examined.

3010
Massachusetts Institute of Technology. Dept. of Electrical Engineering, Cambridge, Mass. THERMOELECTRIC PROCESSES AND MATERIALS. 45p., Jly. 1, 1961. (Semi-annual Prog. Rept.) (Contract Nonr-1841(51)).

The contents include: Anisotropy of thermoelectric power, Mercury telluride evaluation, Mechanical energy flow in perfect lattices, and Investigation of physical properties of materials important in thermoelectric energy conversion.

3011
Merck and Co., Rahway, N. J. STRUCTURAL INVESTIGATIONS IN THERMOELECTRIC MATERIALS, by P. I. Pollak, J. B. Conn, et al. 12p., illus., Nov. 30, 1960. (Prog. Rept. 3) (Contract Nobs-78503) (AD-260 502, but

ASTIA does not supply copies, reference only)

Experiments were performed which indicate that the purity of the Sb used in Alloy 68 preparations has some bearing on the thermoelectric properties of the finished ingot. The greatest changes occur in the thermal conductivity. The data suggest that high purity and very careful doping may be required for the optimization of the figures of merit in this system. Alloy 68 was doped with Hg in order to study the interrelation between thermal and electrical conductivity. The results indicate that the alloy is close to degenerate. Further studies on the Bi, Sb, Se, Te system confirm that the composition close to Alloy 68 shows a steep maximum in the figure of merit. The effect of O on Alloy 68 was investigated by the addition of small amounts of Sb_2O_4. Indications are that O leads to allowering of the thermal conductivity with minor increase in electrical resistivity.

3012
Mochan, I. V. and Smirnova, T. V. AN INVESTIGATION OF THE THERMOMAGNETIC AND GALVANOMAGNETIC PROPERTIES OF p-TYPE PbTe. Fiz. Tverdogo Tela 3:2659-2666, Sept., 1961.

In Russian. Transl. in Soviet Phys. Solid State 3:1936-1941, Mar. 1962.

The thermoelectric mobility force, the electric conductivity, the Hall effect, and the transverse Nernst effect were investigated for four samples whose concentration at room temperature was of the order $5\text{-}8\cdot10^{17}cm^{-3}$.

3013
National Lead Co. Titanium Alloy Manufacturing Division, Niagara Falls, N.Y. THERMOELECTRIC MATERIALS, by M. H. Brooks. 9issues, Nov. 15, 1960 to Jan. 15, 1962. (Bimon. Prog. Repts. 4 through 12) (Contract Nobs-78326).

The reports concern synthesis and processing of certain ceramic materials. Calculations of formulations of many additional compositions have been made.

3014
Naval Engineering Experiment Station, Annapolis, Md. THERMOELECTRIC MATERIALS INVESTIGATION, July 1, 1960 - January 31, 1961, by W. J. Greenert and A. H. Rosenstein. 45p., May 19, 1961. (Prog. Rept.) (Rept. 910158B) (AD 260399).

Thermoelectric properties are reported for nine semiconductor materials. Results are reported for Seebeck coefficient, electrical resistivity, thermal conductivity, and figure of merit. The oxidation characteristics of four thermoelectric materials in oxidizing environments were investigated. Fabrication details of two generating devices were examined and assessed.

3015
Neild, A. B., Jr. INADEQUATE MATERIALS HINDER WIDER USE OF THERMOELECTRIC DEVICES. Soc. Automotive Engrs. J., 70:4145, Feb. 1962.

Ambridged version of paper given at Automotive Engineering Congress, Detroit, Jan. 1962. The need for better materials is discussed; areas of breakdown are described and illustrated with examples from failures experienced during operation of such devices.

3016
New York University. College of Engineering, New York, N.Y. A STUDY OF A CLASS OF INTERMETALLIC COMPOUNDS, THE CHALCOPYRITES, by Irving Cadoff. 12p., illus., Sept. 1961. (Final Rept.) (Rept. ARL 67) (Contract AF33(616)3959) (AD-269 926).

Twenty-five compositions of the form ABC_2 were investigated for possible formation of chalcopyrite semiconducting compounds. Three formed single-phase structures on direct reaction of participating elements and normal solidification. They were $AgInTe_2$, $CuInTe_2$, and $CuFeSe_2$.

3017
Noguchi, Seiichiro. THERMOELECTRIC POWER OF MAGNESIUM-CADMIUM ALLOYS. Phys. Soc. Japan. J., 16:1145-1150, June 1961.

The thermoelectric power was measured relative to pure Cu between room temperature and 300°.

For abstract see Chem. Abs. 55:21825, Oct. 30, 1961.

3018
Noguchi, Seiichiro. THE THERMOELECTRIC POWER OF THE GAMMA-BRASSES. Phys. Soc. Japan. J., 16:1909-1912, figs., Oct. 1961.

The thermoelectric power of the gamma-phase alloys in the copper-zinc system has been measured at room temperature relative to pure copper. The thermoelectric power is found to be a smooth function of composition except in the range between 64.4 and 65.4 at.% Zn where there is a discontinuous change.

Analysis based on a band-approximation suggests that such a discontinuity can be attributed to the extinction of a band of electron holes or the initiation of a band of overlap electrons. However, there is a practical difficulty in distinguishing between the two processes, since the discontinuity occurs in the same and negative direction in either case. This difficulty was overcome with recourse to extra information concerning the Brillouin zone of the gamma-phase, and the discontinuity was interpreted in terms of the electron overlap across the [411] plane.

3019
Ohio State University. Research Foundation, Columbus, Ohio.
THERMOELECTRIC MATERIALS. 4p., May 10, 1961. (Rept. 5) (Contract NObs-78254) (AD 266082).

Studies on NV_6 have shown it to be a promising thermoelectric material with a maximum e.m.f. of about 700 μ v/C in air. This e.m.f. is dependent on ΔT, time and atmosphere to which the hotter end of the molten NV_6 is exposed.

3020
Ohio State University. Research Foundation, Columbus, Ohio.
THERMOELECTRIC MATERIALS, Final Report, by T.S. Shevlin, H.E. Wenden, and S.R. Ali Zaidi. 32p., Sept. 30, 1961. (Rept. 1039) (Contract Nobs-78254) (AD-274831).

Research was directed toward evaluation of molten vanadium oxysalts as thermoelectric materials. Experimental procedures, preparation, and results are presented, the concluding statement being, "formidable difficulties intervene between the apparently promising thermoelectric properties revealed by this study and a practical device".

3021
Oprea, Florea and Balta, Petre. STUDY OF SOME METAL OXIDE SEMICONDUCTORS. Inst. Politeh. Bucureti. Bull. 21:73-86, 1959.

In Roumanian. See Chem. Abs. 56:5515, 1962 for English abstract.

3022
Pacault, A. and Marchand, A. ELECTRONIC PROPERTIES OF PREGRAPHITIC CARBON. J. Chim. Phys. 57:873-891, 1960.

In French. Included in this review are the effect of high temperature treatment on the Hall effect, magnetoresistance, the thermoelectric effect, magnetic susceptibility, electric resistivity, and specific heat.

3023
Paderno, Yu. B., Samsonov, G.V., and Fomenko, V.S. ELECTRICAL PROPERTIES OF LANTHANUM HEXABORIDE. Fiz. Met. i Metalloved. 10:633-635, Oct. 1960.

In Russian. The electrical resistivity of lanthanum hexaboride rose with its porosity, but its thermoelectric power was practically independent of porosity. The temperature dependence (0-2000°C) of the resistivity showed that the compound had typical metallic conduction. (Sci. Abs. 64A:5005, Apr. 1961).

3024
Pearson, W.B. and Templeton, I.M. EFFECT OF DISSOLVED IRON ON THE THERMOELECTRICITY OF SILVER AT VERY LOW TEMPERATURES. Can. J. Phys., 39: 1084-1085, 1961.

Iron causes a very large characteristic thermoelectric power at low temperatures when dissolved in very dilute concentration in Ag: this is similar to its effect in Cu and Au.

3025
Pecheux, H. THERMOELECTRICITY OF ALUMINUM ALLOYS. Acad. Sci. Paris. Compt. Rend., 139:1202-1204, 1904.
In French. Numbers are given showing the emf's for binary alloys of aluminum with

tin, lead, bismuth, magnesium, antimony, and zinc in different proportions. No general conclusions are drawn. (Sci. Abs. 8A:611, 1905).

3026
Pennsylvania University. Moore School of Electrical Engineering, Philadelphia, Pa. RESEARCH INVESTIGATIONS ON THE ELECTRICAL PROPERTIES OF SEMICONDUCTING SELENIUM. 3 issues, Dec. 1952, Mar., Sept. 1953. (Repts. 53-25; 53-30; 54-07) (Contract DA 36-039-sc-5426).

The electrical properties of liquid Se in the 200°to 500°C range were studied by means of simultaneous measurements of resistivity and thermoelectric power.

3027
Petrescu, N., Protopopescu, M., and Drimer, D. THE HIGH QUALITY PURIFICATION OF TELLURIUM. Rev. Roumaine Met. 5:227-237, 1960.

In French. Vacuum distillation of commercial Te (97.8% pure) gave a product of sufficiently high purity (impurity content a few ten-thousands per cent) for use in thermoelectric generators. Purification by zone fusion was also studied. The product obtained by vacuum distillation followed by zone fusion is suitable for semiconductor use in electronics; the impurity content is undetectable by spectrographic analysis but may be determined from the variation of electrical resistivity with temperature. (Brit. Non-Ferrous Met. Res. Assoc. Bull. Note 1294, May 1961).

3028
Pilat, I. M. et al. CERTAIN PROPERTIES OF THE CdSb-ZnSb SYSTEM. Fiz. Tverdogo Tela 2:1522-1525, Jly. 1960.

In Russian. Transl. in Soviet Phys. Solid State 2:1381-1383, Jan. 1961.

The paper describes a more careful investigation into the properties of the CdSb-ZnSb system near the 1:1 composition.

3029
Pittsburgh University, Pittsburgh, Pa. RARE EARTH CHALCOGENIDES, 1 September - 30 November 1960, by A. R. Freda. 4p., tables, Dec. 1, 1960. (Contract Nobs-77068) (AD-266 097). (Tech. Prog. Rept).

Attempts to synthesize Ce_2S_3 by doping were studied. Doping CeO_2 with various additives failed to reduce the resistivity below 1000 megohm/cm. Graphite additions produced a mechanical mixture which had a lower resistivity. Attempts were made to prepare Ce_2S_3 by utilizing H_2S (1200 to 1400°C) and CS_2 (750 to 850°C) as reducing agents in a SiC tube furnace. Ce_2O_2S was synthesized along with various unidentified compounds. X-ray diffraction data were obtained.

3030
Pittsburgh University, Pittsburgh, Pa. RARE EARTH CHALCOGENIDES, 1 April - 1 June 1961, by A. R. Freda. 5p., tables, June 21, 1961. (Tech. Prog. Rept.) (Contract Nobs-77068) (AD-266 094).

Synthesis of pure Ce2S3 by reacting CeO2 with CS2 at temperatures from 800 to 1100C produced a material which failed to agree with ASTM X-ray data for Ce2S3. The CeO2 was compacted so that synthesization and sintering occurred simultaneously. The volume, density, and resistivities of the compacts were measured.

3031
Rocher, Y. A. and Friedel, J. PHENOMENOLOGICAL ASPECTS OF SOME PHYSICAL PROPERTIES OF PLUTONIUM AND OF DELTA-SOLID SOLUTIONS OF PLUTONIUM-ALUMINUM. Phys. & Chem. Solids 18:196-202, 1961.

In French. The low-temperature anomalies of electrical resistivity and thermoelectric power are discussed in terms of an order-disorder transformation. Above the critical temperature short-range order indicates a decrease in the number of conduction electrons/atom from 1 to 0.8 on going from pure δ-Pu to the Pu-10% Al δ-solid solution. The possible nature of the low-temperature order is discussed. The anomalous expansion observed in this system is related to a thermally activated process, the energy of which increases linearly from 0.17 to 0.27 eV/g-atom as the Al atomic concentration increases from 0 to 5%. (Met. Abs. 29:201, Nov. 1961).

3032
Rodot, Michael. L'EFFET MAGNETO-THERMOELECTRIQUE DANS L'ANTIMONIURE D'INDIUM (MAGNETOTHERMOELECTRIC EFFECT IN INDIUM ANTIMONIDE). In International Conference on

Solid State Physics in Electronics and Telecommunications. Proceedings, v. 2, Semiconductors, part 2, p. 680-691, London, Academic Press, 1960.

In French. Abstract in Chem. Abs. 55:9060, 1961.

3033
Rodot, Michael and Benel, H. SUR LES PROPRIETES DE SEMI-CONDUCTEURS UTILISABLES COMME THERMOELEMENTS (CONCERNING PROPERTIES OF SEMI-CONDUCTORS USEFUL FOR THERMO-ELEMENTS). In International Conference on Solid State Physics in Electronics and Telecommunications. Proceedings, v. 2, Semiconductors, part 2, p. 692-698, London, Academic Press, 1960.

In French. Concerns antimony telluride and bismuth telluride.

3034
Rosi, F. HOT CUBES. News Wk. 58:60, Nov. 27, 1961.

A brief news item tells of a recently announced germanium-silicon alloy which operates at twice the temperatures of any other thermoelectric material and is more efficient. It is stated that one square foot of these thermocouples could produce 10 kilowatts of power, three times more than the average household needs. The alloy is ideal for satellies. Other uses considered are silent outboard motors and power lawnmowers.

3035
Samokhvalov, A. A. and Fakidov, I. G. ELECTRIC PROPERTIES OF MAGNETITE. ELECTRICAL CONDUCTIVITY, GALVANOMAGNETIC, THERMOELECTRIC, AND THERMOMAGNETIC PROPERTIES OF MAGNETITE IN THE TEMPERATURE RANGE 80-400°K. In Ferrity, Fiz. i Fiz-Khim. Svoistav, Dok. 3-go[Tret'ego]Vses. Soveshch. 1960, p. 272-285.

In Russian. Brief abs. in Chem. Abs. 55: 7954, 1961.

3036
Schlosser, E. G. ON THE SEMICONDUCTING BEHAVIOUR OF NICKEL OXIDE. Z. Elektrochem. 65:453-462, 1961.

In German. Results of thermoelectric and conduction measurements for NiO are given in three cases; undoped, Li_2O doped and Ga_2O_3 doped. The conduction type in each case is identified and the trap depths determined. The electron and hole mobilities are also given.

3037
Semenov, V. V. and Doroshenko, A. G. PELTIER COEFFICIENT AND THERMAL ELECTROMOTIVE FORCE OF THE ALLOY Bi_2Te_3. Odessk. Tekhnol. Inst. Pishchevoi i Kholodil. Prom. Trudy. 8, no. 2:68-73, 1959.

In Russian. Measurements were made of the thermo-e.m.f., α, and the Peltier heat of cylindrical specimens of the alloy Bi_2Te_3. The measurements of α were made with the usual potentiometric apparatus, while the Peltier heat was measured by a compensation method eliminating the effect of the Lenz-Joule heat generated by the passage of current through the specimen. It follows from the direct determinations of α that $dE/dT = 2.18 \times 10^{-4}$ V/deg C, and from the measurements of the Peltier heat that $\alpha = 2.07 \times 10^{-4}$ V/deg C. It is thus concluded that Thomson's relation $P = \pm T (dE/dT)$, where P is the Peltier coeff., is satisfied for the alloy Bi_2Te_3. (Abs. J. Metallurg. nos. 5/6A:68, 1961).

3038
Southwest Research Institute, San Antonio, Texas.
PROPERTIES OF INORGANIC ENERGY-CONVERSION AND HEAT-TRANSFER FLUIDS FOR SPACE APPLICATIONS, by W. D. Weatherford, J. C. Tyler and P. M. Ku. 470p., Nov., 1961. (WADD TR 61-96) (Contract AF33(616)-7206).

The fluids represented are namely, liquid metals, nonmetals, and gases.

3039
Stanford Research Institute, Menlo Park, Calif.
THERMOELECTRIC MATERIALS, by J. W. Johnson. 6 issues, 1960, 1961. (Bimon. Prog. Repts. 10, 13, 15, 16, 17, and summary (19 October 1958 - 31 May 1961) (Contract Nobs-77017).

Concerns work on cuprous sulfide and cuprous telluride.

3040
Tanuma, Seiichi. THERMOELECTRIC POWER OF BISMUTH-ANTIMONY ALLOYS. Phys. Soc. Japan. J., 16:2354-2355, figs., Nov., 1961.

The thermoelectric power of Bi-Sb solid solution is investigated in the temperature range from 15 to 300°K.

3041
Teramoto, Iwao and Takayanagi, Shigetoshi. PROPERTIES OF $Bi_{2-x}Sb_xTe_{3-y}Se_y$ SYSTEM. J. Appl. Phys. (Japan), 29:400-404, June 1960.

The electrical properties of $Bi_{2-x}Sb_xTe_3$ Se_y with stoichiometric composition of metal components (B_1 and Sb) and metalloid components (Te and Se) are investigated. These materials are prepared by melting, quenching and annealing. It is found that the crossover points of the thermoelectric power from P-type to N-type coincide with the electrical conductivity minima, and value of y corresponding to these intrinsic characteristics increases with increasing x. X-ray observations disclosed a continuous solid solution with rhombohedral structure except in the region where the composition is close to Sb_2Se_3. In the latter region, electrical conductivity and thermoelectric power show discontinuities and admixture phases of rhombohedral and orthorhombic structures appear. Based on a model of chemical bonding in compounds of the type $A_2{}^{V}B_3{}^{VI}$, and explanation is given to the observed results. (Japan Sci. Rev. Mech. & Elec., 7:1247, 1960).

3042
Teramoto, Iwao and Takayanagi, Shigetoshi. RELATIONS BETWEEN THE ELECTRONIC PROPERTIES AND THE CHEMICAL BONDING OF $Sb_xBi_{2-x}Te_{3-y}Se_y$ SYSTEM. Phys. & Chem. Solids, 19:124-129, 1961.

It is reported that y_o, the value of y for which the thermoelectric power reverses from p-type to n-type coincides with the electrical conductivity minimum, and increases with increasing x. The results are explained using a model of chemical bonding in compounds of the type $A_2{}^{V}B_3{}^{VI}$. The system is shown to be a continuous solid solution with hexagonal structure, except for the region whose composition is close to Sb_2Se_3. (Metall. Abs. 29:316, 1961).

3043
Teranishi, Teruo, MAGNETIC AND ELECTRIC PROPERTIES OF CHALCOPYRITE. Phys. Soc. Japan. J.; 16:1881-1887, figs., Oct. 1961.

The present study reports the temperature dependence of the magnetic torque and the susceptibility of a single crystal, giving the Neel temperature and the direction of antiferromagnetism. Experimental results of electric properties, that is, the conductivity, the Hall effect and the thermoelectric power, which show behaviours of typical semiconductors are also given.

3044
THERMOELECTRIC ALLOY EFFECTIVE AT 900C. Aviat. Wk. & Space Tech. 75:80, Nov. 27, 1961.

"Germanium-silicon alloy which offers important advantages as a thermoelectric material has been developed at RCA's David Sarnoff Research Center under a research program initiated by Navy's Bureau of Ships."

"RCA says the new material is most effective in the temperature range between 350C and 900C; those figures include the temperatures of useful heat output from nuclear reactors (about 550C) and gas flames (about 900C). Advantages over currently used lead-telluride thermoelectric materials include higher power density--about four times that of the conventional material--and stability at high temperatures." Entire Item quoted.

3045
Timchenko, I. N. and Shalyt, S. S. THE INFLUENCE OF PHONO DRAG OF THE CURRENT CARRIERS ON THE THERMOELECTRIC POWER OF TELLURIUM. Fiz. Tverdogo Tela 1:1302-1304, Aug. 1959.

In Russian. Transl. in Soviet Phys. Solid State 1:1192-1194, Feb., 1960.

The thermoelectric power of tellurium was measured from 2-300°K. Above the maximum at 7°K the phonon drag component decreases as $T^{-2.7}$ and below the maximum as $T^{0.7}$ in good agreement with Herring's theory.

3046
Uchiyama, Shin and Inoue, Nobuo. THE ELECTRICAL AND THERMOELECTRIC PROPERTIES OF BISMUTH TELLURIDE CRYSTALS PREPARED BY THE ZONE-MELTING METHOD. Inst. Elec. Engrs. (Japan) J., 80:954-959, Jly. 1960.

Zone-refining method of Bi_2Te_3 crystals for thermoelectric elements and some

properties of the products are reported. The method used is the so-called reverse pass method or re-melting in reversed direction. The best crystal obtained has following properties: P-type (Te 48.1 wt.%), $\eta \simeq 190\,\mu V/deg$, $\rho \simeq 0.9 \times 10^{-3}$ ohm·cm, $z \simeq 1.4 \times 10^{-3}\ deg^{-1}$; N-type (Te 55.0 wt.%), $\eta \simeq -160\,\mu V/deg$, $\rho \simeq 0.8 \times 10^{-3}$ ohm·cm, $z \simeq 1.1 \times 10^{-3}\ deg^{-1}$. Crystals doped with iodine by means of the zone-leveling has a figure of merit about $2.8 \times 10^{-3}\ deg^{-1}$ (iodine 0.26 atomic %). (Japan Sci. Rev. Mech. & Elec. 7:3390, 1961).

3047
Van Houten, O.S. SEMICONDUCTION IN $Li_xNi_{1-x}O$. Phys. & Chem. Solids 17:7-17, 1960.

The thermoelectric properties of NiO are determined and discussed in terms of a model involving localized Ni++ ground states and Li+Ni++ acceptor levels.

3048
Weiss, H. III-IV VERBINDUNGEN ALS HEISSLEITER (III-IV THERMOELECTRIC COMPOUNDS). In International Conference on Solid State Physics in Electronics and Telecommunications, Brussels, 1958. Proceedings, v.2, part 2, p.794-801. New York, Academic Press, 1960.

In German. See Chem. Abs. 55:11098, 1961 for English abstract.

3049
Wernick, J.H. and Wolfe, R. THE SEARCH FOR NEW SEMICONDUCTORS. Bell Labs. Rec. 39:388-394, Nov. 1961.

Survey of ternary semiconductors; structure, optical properties and the Hall coefficient. Ag/Sb telluride suitable for thermoelectric power generation between 200-500C.

3050
Westinghouse Electric Corp., Atomic Power Department, Pittsburgh, Pa.
THERMOELECTRIC NUCLEAR FUEL ELEMENT, Quarterly Progress Report and Final Report, by G.R. Kilp and others. 3 issues, Jan., Apr. 1961, Feb. 1962. (WCAP-1695, WCAP-1745 and WCAP-1715) (Contract AT(30-3)500).

Materials prepared for evaluation of thermoelectric properties included PbTe, USe, and USTe.

3051
Westinghouse Research Laboratories, Pittsburgh, Pa.
THERMOELECTRICITY. v.p., Jan. 15, 1958. (Prog. Rept. 1) (Contract NObs-72361) (AD-213 742).

The report starts with a review of the basic phenomenon of thermoelectricity, recapitulates the technical break-through which led to the present contract and finally discusses the objective of the contract which is to develop materials and a 5 kilowatt thermoelectric generator for ship propulsion.

3052
Westinghouse Research Laboratories, Pittsburgh, Pa.
THERMOELECTRICITY. 4 issues, Feb., May, Aug., Nov. 1961. (Quart Prog. Repts. 1-4) (Contract NObs-84317).

Reports are given on thermoelectric properties of various rare earth chalcogenides, solution preparations, and high-temperature liquid thermoelectric materials.

3053
Westinghouse Research Laboratories, Pittsburgh, Pa.
THERMOELECTRICITY. v.p., Aug. 1, 1961. (Quart. Prog. Rept. 1) (Contract NObs-84687) (AD-266 220).

The first part of this report is the paper "Theoretical Requirements for Thermoelectric Materials," by P.G. Klemens, Sci. Paper 929-8904-R3, and gives a first order correction to the theory of mixed valence semiconductors. Of interest to the thermoelectric work is the fact that these correction terms act to lower both the Seebeck coefficient and the electrical conductivity, thereby further lessening their desirability as thermoelectric elements. The second paper, "Model for the Electronic Transport Properties of Mixed Balence Semiconductors," by R.C. Miller, R.R. Heikes, and R. Mazelsky, Sci. Paper 929-8904-P1, describes a new and rather novel approach to the design of thermoelectric materials. Therein it is shown that it may be possible to alter metals in a quite beneficial way.

3054
Westinghouse Research Laboratories, Pittsburgh, Pa.
THERMOELECTRICITY. 1/4 in. thick,

Oct. 1, 1961. (Quart. Prog. Rept. 2) (Contract NObs-84687)

The following papers are included: The Dependence of the Thermoelectric Figure of Merit on Energy Band Width, by R. C. Miller, R. R. Heikes, and A. E. Fein; Lattice Thermal Resistance at Normal and High Temperatures due to Point Defects, by P. G. Klemens; Comments on "Thermal Conductivity in Two-Phase Alloys," by R. W. Ure, Jr.; and Thermoelectric Effects in Non-Linear Junctions, by R. W. Ure, Jr.

3055
Yahia, J. and Frederikse, H. P. R. ELECTRICAL CONDUCTION IN p-TYPE TITANIUM SESQUIOXIDE. Phys. Rev. 123:1257-1261, Aug. 15, 1961.

The Hall effect, thermoelectric power and electrical conductivity have been measured as a function of temperature in crystals of p-type titanium sesquioxide. A transition is observed at about 450°K. Below this temperature the crystals behave like semiconductors, while above it the conductivity is apparently metallic.

3056
Yazliev, S. AN INVESTIGATION OF THE THERMOELECTRIC PROPERTIES OF NICKEL-PALLADIUM ALLOYS. Zhurn. Neorg. Khim. 5:2446-2457, 1960.

In Russian. The thermoelectric properties of Ni-Pd alloys (10-90 at.% Ni, 90-10 at.% Pd) were investigated in the range 0-1000°C. The error in the measurements of the differential thermo-e.m.f. was 2-8%. The integral thermo-e.m.f. was measured with a potentiometer in combination with Pt. All thermoelectric properties change in a steady manner, which is typical of a continuous series of solid soln. The sign of the thermo-e.m.f. of all the alloys investigated is negative, indicating that electron conduction predominates in these alloys. The magnetic transformation in Ni-Pd alloys is characterized by breaks in the curves of differential thermo-e.m.f., abs. thermo-e.m.f. and thermoelectric potential. Like the sp. ht. of metal, the Thomson e.m.f. (sp. ht. of current carriers) shows a discontinuity at the point of second-order transition (magnetic transformation).

3057
Zaitov, F. N. THERMOELECTRIC EFFECT IN THIN FILMS OF ANTIMONY AND BISMUTH. Sbornik Nauch. Rabot Stud. Kirgiz. Univ. 2:27-31, 1959.

In Russian. For summary taken from Referat. Zhur. Met., 960, Abs. 6008, see Chem. Abs. 55:6078, Apr. 3, 1961.

3058
Zdanowicz, W. THERMOELECTRIC PROPERTIES OF CADMIUM ARSENIDE (Cd_3As_2). Acta Phys. Polon. 20:647-656, 1961.

Measurements of the thermoelectric power of Cd_3As_2 gave a $\cong -60\ \mu V/°C$ at 250°C with respect to Cu. From the temperature dependence of a between 25 and 400°C, the value of the reduced Fermi level and its temperature dependence $n = \zeta/kT$ was estimated. Within the investigated temperature range n was larger than 2.8. Hence it follows that the Fermi level is situated within the production band, and the electron gas in Cd_3As_2 is degenerate. From the temperature dependence of n a correction for electron gas degeneracy was introduced into the terms of mobility and concentration of electrons. The magnitude of effective electron mass in Cd_3As_2 at 25°C amounts to $m_n^* = 0.046\ m_o$. In extrinsic range $m_n^*/m_o \sim T^{0.9}$. A qualitative attempt was undertaken to explain the difference between the width of forbidden and obtained from the optical absorption edge (0.6 eV) and that obtained from the Hall coefficient and electrical conductivity (0.14 eV). (Sci. Abs. 64A:17811, Dec., 1961).

E. Design, Principles of

3059
Corry, T. M. and Spira, G. THERMOELECTRIC GENERATOR DESIGN, PERFORMANCE, AND APPLICATION. Inst. Radio Engrs. Trans. MIL-6:34-40, figs., Jan., 1962.

Many of the practical problems that are encountered in building present-day generators are illustrated. A design procedure for free convection air-cooled generators is described. The performance of power thermocouples as a function of junction temperature is discussed and curves illustrating couple efficiency, power output, heat flux and voltage as a function of hot junction temperature are shown.

The effects of varying thermocouple length on generator efficiency and generator specific power are shown graphically and methods

of predicting generator performance are illustrated for thermoelectric materials of equal figures of merit but different values of thermal conductivity. The paper also discusses free convection heat exchangers and fossil-fuel burners. The thermoelectric generator performance on a watts-per-pound basis is compared with battery- and gasoline-engine-driven generator performance for specific missions.

3060
Gross, E. T. B. EFFICIENCY OF THERMOELECTRIC DEVICES. Am. J. Phys. 29: 729-731, Nov. 1961.

The known expressions for various efficiencies of thermoelectric energy converters can be so modified that the Carnot efficiency η_c of the ideal heat engine cycle appears as one of two significant parameters. The other parameter ZT(Z= figure of merit, T = hot spot temperature in ^{o}K) is a significant characteristic of the thermoelectric material used in the device. Using these parameters leads to a realistic evaluation of presently possible efficiencies under ideal conditions.

3061
Naval Ordnance Laboratory, White Oak, Md. FEASIBILITY OF DESIGNING A THERMOELECTRIC GENERATOR TO UTILIZE REENTRY HEATING, by W. N. Knutsen. 66p., June 30, 1961. (Tech. Rept. 61-44).

Thermoelectric generators which utilize latest materials can obtain efficiency of up to 10% in steady state operation and have promise of meeting the missile power supply requirements of high reliability in operation after long term storage and high radiation exposure.

3062
Reich, A. D. and Madigan, J. R. TRANSIENT RESPONSE OF A THERMOCOUPLE CIRCUIT UNDER STEADY CURRENTS. J. Appl. Phys. 32:294-301, Feb., 1961.

Heat transfer calculations for a thermocouple circuit functioning as a Peltier cooler are presented.

3063
Talaat, M. E. ELECTRIC ANALOG OF TRANSPORT PHENOMENA IN A THERMOELECTRIC GENERATOR. Comm. & Electron. no. 56, p. 427-431, Sept. 1961. Paper given at AIEE Winter General Meeting, New York, January 29 - February 3, 1961, Paper 61-188).

Derivation of an electric circuit analog of a thermoelectric-couple arm, where the thermal conductances are represented by electric conductances, and where the rates of Peltier, Joule, and Thomson input heat and the electric power output are represented by current sources. The equivalent thermal circuit is shown to satisfy the transport equations, and is then applied to the derivation of an overall thermal equivalent circuit of a typical isotope-fueled thermoelectric generator. The dimensions and physical constants which enter into the expressions for the parameters of the thermal equivalent circuit are also yielded by the method.

3064
Weiss, A. L. THERMOELECTRIC GENERATOR DESIGN. In Symposium on Design with Materials That Exhibit Brittle Behavior, v. I, p. 357-358, Washington, D. C., National Academy of Sciences-National Research Council, Oct. 20, 1961.

Application of a design with a brittle material which circumvents its brittle characteristics in application to thermoelectric generators is discussed.

F. Applications

1. Power Generation

3065
Angello, J. and Shorr, W. CRYOGENIC FUELED THERMOELECGRIC GENERATORS. In Power Sources Conference. Proceedings, 15th, 1961, p. 134-139, Red Bank, N. J. PSC Publications Committee, 1961.

Initial experiments to determine the feasibility of using a cryogenic fuel, such as liquid nitrogen as a source of energy to produce electrical power from thermoelectric materials are described. Production of 875 milliwatts output power from a single thermocouple at a temperature difference of only 126°C indicates great promise.

3066
Brands, F. W. TWO HOT JUNCTIONS UP THERMOCOUPLE OUTPUT. Electron. 34:118, 120, Apr. 28, 1961.

Heating both junctions of an experimental

thermocouple produced more net voltage than when one of the junctions was cooled. The junctions for this unusual thermoelectric generator were made of materials having nonlinear voltage-temperature characteristics. If semiconductor materials with the desired properties could be found for the junctions, conversion efficiency could be significantly increased.

3067
California Institute of Technology. Jet Propulsion Laboratory, Pasadena, Calif. PRELIMINARY EVALUATION OF A SNAP-III THERMOELECTRIC GENERATOR FOR SPACE-CRAFT SECONDARY POWER, by O.S. Merrill. May 15, 1961. (Tech. Memo. 33-33).

This memorandum presents a discussion of the preliminary experimental evaluation, performed in 1959, of the SNAP-III generator as a source of space-craft secondary power. (Astron. Info. Abs. 4: 4246, Sept. 1961).

3068
Douglas Aircraft Co., El Segundo, Calif. FEASIBILITY STUDY AND INVESTIGATION OF THERMOELECTRIC POWER GENERATION AND COOLING FOR FLIGHT VEHICLES, by J.F. Hood. 2 issues, June, Jly. 1961. (Interim Rept. 1, 2) (Repts. THMR-25-1; THMR-25-2) (Contract NOw-61-0404-t) (AD-260 527; AD-265 635).

A study to determine the electrical requirements such as voltage, frequency, and power required by military aircraft and missiles was started.

3069
Fenity, R.D. HIGH VOLTAGE OUTPUT WITH OXIDE THERMOELECTRIC GENERATORS. Electron. 35:39-41, Feb. 2, 1962.

Ceramic technology is used to produce an experimental thermoelectric generator capable of producing 100 volts in a twenty cubic inch package heated to 2,400 degrees F.

3070
Ft-Sq THERMOELECTRIC SOURCE GENERATES THREE-HOUSE POWER. Mach. Design 33:15, Dec. 7, 1961.

A new material, an alloy of germanium and silicon is reported. Laboratory tests indicate that a generator using plates of the material (1 sq ft surface area) heated to about 1800 F produces 10 kw of electricity - nearly three times the amount consumed at any given time in the average home.

3071
General Atomic. John Hays Laboratory for Pure and Applied Science, San Diego, Calif. SOLAR THERMOELECTRIC PANELS. 16p., Nov. 10, 1961. (Rept. GACD-2761) (Quart. Rept. 4) (Contract AF33(616)-7676).

The report concerns thermoelectric element fabrication, fabrication of test panels, collector coatings, emitter coatings, sublimation of zinc antimonide, thermal expansion and contraction, and electrical power characteristics.

3072
General Electric Co., Utica, N.Y. RESEARCH AND DEVELOPMENT ON THERMOCOUPLE ENERGY CONVERTERS (PHASE II), by W.J. van der Grinten. 13p., Nov. 1, 1961. (Quart. Prog. Rept. 2) (Contract DA 30-069-501-ord-3294) (AD-269 034).

Current emphasis has been placed on perfecting the casting-type filling techniques and the completion of the cell design. The casting technique has been perfected so that n- and p-type cells can be manufactured in quantity. The thermoelectric performance of these cells will be measured.

The design and fabrication of the complete cell assembly including a hermetic seal at the cold junction side, having a maximum temperature capability of 780°C has been realized. These cells will be mounted on specially designed matrices for assembly into thermoelectric energy converters to be evaluated by the customer.

3073
General Electric Co., Schenectady, N.Y. THERMOPILE GENERATOR FEASIBILITY STUDY. Part I. SUMMARY, Part II. MATERIALS INVESTIGATIONS, Part III, PERFORMANCE STUDIES, Part IV. GENERATOR DESIGN. Final Reports. 4 issues, Aug. 1960. (WADD TR 60-22, Parts I, II, III, IV). (Contract AF 33(616) 5281) (AD-268 590, AD-265 599, AD-264 926, AD-268 591).

A detailed description is given of the work on junction fabrication and test and on

thermoelectric generator design as applied particularly to: (1) efforts to design, build, and test a 5 watt generator model; and, (2) preparation of specifications for a 100 watt solar thermoelectric generator. The actual specifications for the 100-watt solar thermoelectric generator are appended.

3074
Gevert, F.G., Wang, S. and Broze, R.U. HEAT TO A.C. CONVERSION USING THERMOELECTRIC GENERATORS AND TUNNEL DIODES. Solid State Electron., 3:100-104, Sept. 1961.

The output of a single-cell thermoelectric generator can be converted into high-voltage low-current power by using a high-current tunnel diode as a d-c to a-c converter.

3075
Gurov, V. THERMOELECTRIC GENERATOR [AND] PHOTOELECTRIC PHENOMENA. In Poluprovodniki v Tekhnike i v Bytu, p. 82-105, Moscow, 1958.

In Russian. Transl. no. MCL-446/1, 26p., Oct. 26, 1960. Order from OTS or SLA. (AD-257 134). (Tech. Trans. 6:872, Dec. 12, 1961).

3076
United Aircraft Corp., Hamilton Standard Division, Broad Brook, Conn. A SOLAR THERMOELECTRIC GENERATOR SYSTEM STUDY, by J.R. Ferrara. 266p., Nov. 1961. (ASD TR 61-315) (Contract AF 33(616)-7358).

A theoretical paper design study of a 1500-watt power supply for a vehicle in a 300-mile earth oriented orbit is presented. A mathematical treatment is given for heat transfer and thermoelectric analysis, energy storage requirements, and supporting structure stress analysis.

The design, fabrication, and development testing of a 5-watt ground model is also presented.

3077
United Aircraft Corp., Hamilton Standard Division, Broad Brook, Conn. MODULAR DESIGN OF IMPROVED SOLAR CONVERTERS. 2 issues, Aug., Nov. 1961. (Quart. Prog. Rept.) (Rept. 1, 2) (Contract DA 36-039-sc-87461) (AD-269 232 and 274 478).

Purpose of the program is to investigate and develop materials and design parameters for the construction of solar converters for use in ground military applications in a world-wide environment. The program requires that the solar converter be of a modular design such that it can be expanded to obtain various power levels and adjustable to several voltage levels. It also requires that the converter be easily stored, transported and erected. Experimental models are required to demonstrate the feasibility of the design.

3078
Lang, Ronald and Lubin, Barry. ON AGREEMENT BETWEEN EXPERIMENTAL AND THEORETICAL PERFORMANCE OF A BASIC SOLAR THERMOELECTRIC POWER UNIT. IAS Annual Meeting, 30th, New York, Jan. 22-24, 1962. (Paper 62-45).

Description of a logical design procedure for a thermoelectric power unit, and comparison of the theoretical performance with results of over 100 hrs of prototype testing. Correlations for combining several of the uncontrollable variables affecting the test data are developed. Good agreement is shown between theoretically predicted values of performance parameters and those measured experimentally. (Intern. Aerospace Abs. 62-1428).

3079
Lang, Ronald and Lubin, B.T. A BASIC THERMOELECTRIC UNIT - SEEKING EXPERIMENTAL AND THEORETICAL PERFORMANCE AGREEMENT. Aerospace Eng. 21:6-15, illus., Feb., 1962.

A logical procedure for the design of a solar thermoelectric power unit for planetary fly-by vehicles or orbital satellites is described. Theoretical performance is shown to agree with the results of prototype tests.

3080
Martin, Co., Nuclear Division, Baltimore, Md. AERODYNAMIC RE-ENTRY ANALYSIS. TASK 2. THERMOELECTRIC GENERATOR SUMMARY REPORT, by Robert Oehrli. 41p., 1960, decl. Apr. 27, 1961. (MND-P-2291) (Contract AT(30-1)-217).

An analytical trajectory and aerothermodynamic analysis of a satellite containing a Task 2 thermoelectric generator was

completed. Results show that upon natural decay from a successful mission, the radio-cerium fuel will burn up in space at high altitude, thus only a very minor amount of radio cerium will be released to the stratosphere. (Nuclear Sci. Abs. 16: 3965, Feb. 15, 1962).

3081
Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass.
A DESIGN OF A SMALL HOMOPOLAR MOTOR, by G. J. Bukow. 46p., Jan. 1961. (ASD TR-61-101) (Contract AF33(616)-7624).

Work was undertaken with a view toward using a small homopolar motor as a component of a thermoelectric energy-conversion system, utilizing the low-voltage, high-current out-put of a thermo-electric generator to drive the desired load. Results obtained from the design study have shown distinct possibilities in this direction.

3082
Moreland, W. C. A 500 WATT THERMO-ELECTRIC GENERATOR DESIGN. In Power Sources Conference. Proceedings, 15th, 1961, p. 139-142, Red Bank, N. J., PSC Publications Committee, 1961.

Basic features are outlined, of several designs of air cooled generators, to indicate the performance of specific units, and to show what capabilities will be available in the near future with improved designs. The generators discussed have an effective thermoelectric figure of merit of approximately 1×10^{-3} per °C over the temperature range of 100 to 550°C.

3083
Minnesota Mining and Manufacturing Co., St. Paul, Minn
"MAN-PACK" 250 WATT THERMO-ELECTRIC GENERATOR, Final Report, by A. H. Mayala, D. D. Schley, and W. G. Krawczak. 50p., Nov. 21, 1961. (Contract NObs-78198).

Two complete generator systems were constructed and tested, along with a number of text fixtures for determining the necessary design parameters for the component parts. Results are summarized and discussed.

3084
Monsanto Research Corp., Dayton, Ohio.
HIGH TEMPERATURE THERMOELECTRIC GENERATOR, by C. M. Henderson, R. G. Ault, et al. 23p., illus., Dec. 29, 1961. (Rept. 2509) (Quart. Tech. Prog. Rept. 1) (Contract AF33(657)-7387) (AD-269 887).

Applied research and development is reported on a laboratory thermoelectric generator operating at a hot junction temperature of 1200 C and a 1/100,000 mm Hg. Apparatus needed to fabricate and test candidate junction materials and modules for use with a new proprietary thermoelectric material, MCC 50, are described.

3085
NEW TYPE OF THERMOELECTRIC GENERATOR. Przeglad Telekom. 34:194, June 1961.

In Polish. This is a brief description of a new type of thermoelectric generator designed by the General Instrument Corporation. The generator is designed for supplying electronic equipment and non-supervised electrical installations. (JPRS:10479, Oct. 9, 1961).

3086
Owczarski, W. A. RESISTANCE AUTOBRAZING OF WIRES TO INTERMETALLIC THERMOELECTRIC MATERIALS. Welding J. 40:517-521, May 1961.

A welding process, resistance autobrazing, permits the joining of metallic probes to compound thermoelectric materials. Several of these materials are successfully equipped with probes. Iron, chromel, alumel and platinum probes, among others, are joined to PbTe, Bi_2Te_3 and ZnSb. Wires of several diameters and samples of different geometries are used. The developed process resembles brazing. However, one of the materials to be joined provides filler metal to the joint. The process uses resistance heating to provide the energy required to melt the "filler metal" and complete the joint. (Nuclear Sci. Abs. 15:21128, 1961).

3087
THERMOELECTRIC POWER USED FOR HEATER FANS AND LIGHTED BUOYS. Corr. 16:58, Nov. 1960.

A brief article, with an illustration, gives

details of thermoelectric generators which have been developed to power lighted buoys and to operate a fan to circulate warm air in a gas fired wall heater.

3088
Omuro, Yuzo. BISMUTH TELLURIDE THERMOBATTERY. J. Appl. Phys. (Japan), 29:395-400, June 1960.

Performances of a thermobattery composed of 40 thermocouples, mounted in a heat-storing box covered with glass plates are experimented. The figure of merit Z of the material is $2.29 \times 10^{-3}/^{o}K$ at room temperature, and the highest thermocouple efficiency realized in the experiments was 1.76% under the temperature difference of 49.5°C. The efficiency of heat absorption depended on the nature of the surface, the area and the temperature of the heat collector as well as on the condition of shielding. It ranged from 36% to 39% hence the highest over-all efficiency obtained experimentally was 0.69%. A material having mean Z value of $3.5 \times 10^{-3}/^{o}K$ over the temperature range considered may be expected, and by assuming a possible heat absorption efficiency of 70%, it is promising that about 3% of the incident solar energy will be converted into electricity under a temperature difference of about 80°C. This implies the practicability of Bi_2Te_3 thermobatteries to some extent. (Japan Sci. Rev. Mech. & Elec. 7:1249, 1960).

3089
SEMI-METAL BONDS THERMOELECTRIC PARTS. Mat. Design Eng. 55:9, illus., Jan. 1962.

Gereralock, the new material and processing technique, cuts junction resistance and power losses. A brief explanation is given of how it can be used.

3090
Stremler, F.G. and Gray, P.E. THE INITIAL TRANSIENT BEHAVIOR OF A THERMOELECTRIC GENERATOR. Comm. & Electron., no. 56, p. 367-372, Sept. 1961.

As the efficiency of thermoelectric generators becomes higher, their transient behavior gains in importance. The problem of predicting the time-dependence of the output current is treated first and the important problem of device settling-time is considered. Since the sytem is non-linear in terms of current, a perturbative method is used to obtain a solution.

3091
THERMOELECTRICITY SLATED FOR NEW REMOTE USES. Chem. Eng. 68:64, Aug. 7, 1961.

Advances in direct conversion of heat to electricity are making possible compact power packs that can operate unattended in isolated locations.

3092
Tormazov, F. THERMOELECTROGENERATOR, TYPE TK-2-2. Radio (USSR), no. 2:23, 1956.

In Russian. Air Technical Intelligence Service Transl. no. MCL-143(III) is available. Also available from OTS and SLA.

The heat energy from a kerosene lamp is converted into the electric power for supplying power to radio receivers, "Rodina-47," "Rodina-52" and "Iskra." During the operation of thermoelectrogenerator this kerosene lamp can serve simulataneously for illumination of the room. (Tech. Transl. 6:795, Nov. 29, 1961).

3093
Vergnolle, J. PLANE THERMOELECTRIC SOLAR GENERATOR. Ann. Radioelec., 16:128-154, Apr. 1961.

In French. Examines in detail the operation of plane thermoelectric solar generators, these being the simplest system and the most rugged from the technological point of view, for collecting solar energy, transforming it into heat flow through semi-conductor thermocouples, and finally obtaining electric power. A very large number of charts help calculation of the various heat flows within the generators and the determination of optimum structures. From these optimum structures, other charts supply the values of the electric power available and of the daily energy which can be relied on. Attention is called to the main delicate design points and to the influence of their imperfections in actual practice on performance. The way is thus prepared for the construction of generators capable of competing successfully with photo-voltaic cells. (Sci. Abs., 64B: 5496, 1961).

3094
Westinghouse Electric Corp., Cheswick, Pa. 5KW THERMOELECTRIC GENERATOR, by J.C. Kastovich, M.D. Fisher, and W.C. Moreland. 31p., Aug., 1960. (Preliminary Rept.) (Rept. 9160-01102-903(1)) (Contract NObs-77093) (PB 158898).

The design, fabrication, and testing of a high-power, fossil-fuel-fired thermoelectric generator is discussed. The history of development of the component systems is also summarized. Results of both full-scale generator testing and individual module testing is presented. (Res. Repts. 37:S-14, Jan. 20, 1962).

3095
Westinghouse Electric Corp., Lima, Ohio. EXPERIMENTAL MEASUREMENTS AND ANALYSIS OF DEGRADATION FACTORS AFFECTING LONG LIFE FEASIBILITY OF THERMOELECTRIC GENERATORS. 78p., Apr. 1961. (WADD TR 61-107) (Contract AF33(616)7515).

Life test module testing has shown that for extended lifetime of operation at elevated hot junction temperatures (550-600°C), thermoelectric generators of the type PN 908D301 must be operated with the thermoelectric couples in an inert or reducing atmosphere to reduce deterioration due to contact oxidation. Tests have shown that that the generators behave like chemical batteries.

2. Heat Pumps (Refrigeration--Temperature Control)

3096
Aoki, Masaharu, THERMOELECTRIC COOLING BY BISMUTH-TELLURIDE THERMOJUNCTIONS. 6. ABSOLUTE MEASUREMENT OF HEAT ABSORBING POWER. J. Appl. Phys. (Japan), 29:371-373, June 1960.

The heat absorbing power at the cold junction is measured in vacuum under various heat loads. The value of the performance coefficient predicted by the theory is found to agree fairly well with the experimental data. It shows that, for designing practical thermoelectric cooling, theoretical calculation on heat absorption can be relied upon. (Japan Sci. Rev. Mech. & Elec. 7:1239, 1960).

3097
Aoki, Masaharu. THERMOELECTRIC COOLING BY BISMUTH-TELLURIDE THERMOJUNCTIONS. 4. MEASUREMENT OF HEAT ABSORBING POWER. J. Appl. Phys. (Japan), 28:88-90, Feb., 1959.

Heat absorbing power at the cold junction measured under various loads. With a thermojunction that showed a temperature difference of 28 deg in vacuum, the difference in still air was 23 deg., and the heat absorbed at the cold junction was 0.032 cal/sec. The coefficient of performance deduced from the experiment was 11%, showing fairly good agreement with theoretical value 12%. (Japan Sci. Rev. Mech. & Elec. 6:81, 1959).

3098
APPLICATIONS OF PELTIER COOLING EFFECT. Elec. Eng., 78:408-409, Apr. 1959.

This is a brief note regarding research on materials and techniques required for thermoelectric cooling started at Battelle Memorial Institute under the sponsorship of 16 American industrial firms.

3099
Arai, Sotaro, and others. THERMOELECTRIC COOLING BISMUTH-TELLURIDE THERMOJUNCTIONS. 7. TEMPERATURE CONTROL OF PHOTODEVELOPING VATS. J. Appl. Phys. (Japan), 29:374-375, June 1960.

Cooling experiment has been carried out with a vat of 2000 cc at a room temperature of 28°C. The vat temperature dropped from 20°C to 7°C in two hours with 180 watt input to the panel. (Japan Sci. Rev. Mech. & Elec. 7:1246, 1960).

3100
Borg-Warner Corp., Chicago, Ill. INFRARED CELL ELECTRONICALLY REFRIGERATED. Final Report, by G.F. Boesen, A.D. Reich, and C.E. Rufer. 91p., illus., Sept. 1961. (ASD TR-61-369) (Contract AF33(616)-7133) (AD-262 961).

An investigation was made of the feasibility of combining an infrared detector cell and a thermoelectric cooler in one package capable of providing a combined sensitivity and reliability not hitherto available. A total of six ICER units

(infrared cell electronically refrigerated) in three different configurations were built and successfully operated. Thermoelectric temperatures as low as -85°C from a +27°C heat sink were obtained with a detector under bias load. The indium antimonide detectors thus cooled had detectivities as high as $D^* = 1.1 \times 10^9$ sq/cm/watt. Details of analytical and experimental studies of thermoelectric cascade theory, detector theory and heat transfer are covered. The design approach and evaluation of the final ICER units are included.

3101
Burnett, T.B., Lorch, H.O., and Thompson, J.E. SOME PROBLEMS IN THE DEVELOPMENT OF A COMMERCIAL THERMOELECTRIC REFRIGERATOR. Brit. J. Appl. Phys. 12:595-602, Nov., 1961.

Two basic problems in the development of a thermoelectric refrigerator are the construction of a cooling unit, consisting of the thermoelectric junctions, and the complete refrigerator design which makes best use of the thermoelectric material. It is essential for the unit to achieve good thermal contact with the cooling chamber and to have good electrical contact across the p and n semiconductor bars forming each junction. A simple but accurate method for measuring the junction resistance is shown, and the relative merits of various methods of forming the cooling unit are discussed. The heat balance equations for a refrigerator are given which include the cooling fin system, and the method of optimization of the design is noted. (Sci. Abs. 64A(Pt.II):18751, Dec. 1961).

3102
Carrier Corp., Research and Development Division, Syracuse, N.Y.
THERMOELECTRIC AIR CONDITIONING SYSTEMS FOR SUBMARINES, Final Report, Phase I, by S.F. Gilman and G.D. Hudelson. 1v., illus., Oct. 31, 1959. (Prog. Repts. 1-5) (Contract NObs-77112) (AD-263 002).

A study was made of submarine heating and cooling requirements, and in addition to, analysis of thermoelectric air conditioning system design and performance characteristics as related to submarine application. Air conditioning loads existing on the SS(N)593 submarine were analyzed and an evaluation of off-design requirements was made. The results of an investigation of various types of thermoelectric air conditioning systems were presented with particular reference to power, weight and size. Two systems have been studied in detail; namely, system B (thermoelectric water chiller with conventional air cooling coils) and system G (conventional central sea water heat exchanger with thermoelectric air coolers). General information relating to the selection of a particular design point for a thermoelectric system has been presented. A somewhat arbitrary design point has been selected in order to illustrate performance characteristics over a complete range of operating conditions.

3103
Carrier Corp., Syracuse, N.Y.
THERMOELECTRIC AIR CONDITIONING SYSTEMS FOR SUBMARINES, Final Report, Phase II, by G.D. Hudelson. 1v., illus., Nov. 1960. (Prog. Repts. 1-4) (Contract NObs-77112) (AD-263 003).

The preliminary design of a model thermoelectric air conditioning system and the fabrication and experimental evaluation of thermoelectric components and subassemblies representative of the system design was undertaken. The design was based on a system suitable for integration into a submarine of the SS(N)593 class for the heating, cooling and dehumidifying requirements of a specific sub-compartment area. The results obtained from experimental and analytical studies of two thermoelectric air cooler modules are reported, and a preliminary design of a 1-ton thermoelectric air cooler is presented. Design and off-design performance predictions for the 1-ton system are included based on analog computer studies and the experimental qualification of the predicted performance of the two thermoelectric modules. The results obtained under this program are considered to be positive indications of the feasibility of going ahead with the next phase of work leading to the ultimate application of thermoelectricity for submarine air conditioning.

3104
Dörr, W. DAS FRIGISTOR-DIAGRAMM. (FRIGISTOR). Elektron. Rund. 15:156-158, Apr. 1961.

In German. Thermocouples of semiconductor materials for use as cooling elements and heat pumps are discussed.

Various patterns of commercial-type Bi-Te junctions using the Peltier effect are described. (Electron. Tech. 38: A203, Dec. 1961).

3105
ERDL TESTING THERMOELECTRIC AIR CONDITIONER. Army Res. and Devlpt. News Mag., 3:4, Feb. 1962.

A brief article describes a new type of air conditioner being tested at the U.S. Army Engineer Research and Development Laboratories, Fort Belvoir, Va. Employing thermoelectric principles instead of refrigerant gases, it is directed primarily to Army missile needs, but "exciting" commercial development possibilities are envisioned.

3106
Goldsmid, H.J. THE THEORY AND APPLICATION OF THERMOELECTRIC COOLING ELEMENTS. Radio & Electron. Comp., 1: 246-249, figs., Mar. 1960.

A return to the study of certain scientific principles discovered early in the nineteenth century aided by new knowledge gained from research on semiconductors has led recently to interesting developments in the technology of thermoelectric cooling.

3107
Haacke, G. ELEKTROTHERMISCHE KUEHLELEMENTE UND IHRE ANWENDUNGEN (ELECTROTHERMAL COOLING APPLIANCES AND THEIR APPLICATIONS). Ver. Deut. Ing. Z., 103: 753-754, June 11, 1961.

In German. The Peltier effect is nowadays being utilized for cooling purposes. Temperature differences of up to 80°C can already be achieved with single units, larger temperature differences with cascade arrangements. This apparatus can be used at present only for small objects, and is not very efficient. In the case of germanium rectifier units the efficiency is about 60%. The equipment is suitable for specialized types of small domestic refrigerators. (Elec. Eng. Abs. 64: 6795, Dec. 1961).

3108
Hermach, F.L. THERMAL CONVERTERS AS AC-DC TRANSFER STANDARDS FOR CURRENT AND VOLTAGE MEASUREMENTS AT AUDIO FREQUENCIES. J. Res., 48: 121-138, Feb. 1952.

Equations which govern the temperature rise of a conductor heated by an electric current and cooled by conduction (to relatively massive terminals) are solved in this article. These same equations are used to establish the steady-state midpoint temperature rise on DC with Peltier and Thomson heating in addition to ordinary resistance heating. The DC error of a thermal converter is calculated.

3109
IMPULSE-OPERATION OF COOLING THERMOELECTRIC CELLS. Zhurn. Tekh. Fiz. 28: 489-492, 1958.

In Russian. A general expression for the temperature of the cold junctions of a thermoelement is derived. It is shown analytically and experimentally that the inertia of a thermoelement is proportional to the square of its linear dimensions, and that the rate of cooling is proportional to the magnitude of the current. When a pulsating current of an amplitude greater than the optimum current under steady conditions is employed, the inertia is greatly reduced and short-time cooling effects, considerably larger than the maximum obtainable under steady conditions, can be secured.

3110
Michigan State University, East Lansing, Mich.
ON THE POSSIBILITY OF THERMOELECTRIC REFRIGERATION AT VERY LOW TEMPERATURES, by F.J. Blatt. 9p., Nov. 1961. (AFOSR-1703) (Contract AF49(638)-70) (AD-267 633).

Peltier cooling is discussed, specifically the feasibility of using this technique at very low temperatures (4.2°K or less).

3111
Northrop Corp. Nortronics Div., Hawthorne, Calif.
DETECTOR CELL AND COOLER PACKAGE. 10p., illus., Jan. 20, 1961. (Quart. Rept. 2) (Rept. 61-13) (Contract AF33(616)7573) (AD-260 383).

Progress is reported on the development of a Peltier effect device for the cooling of an infrared detector to -78°C through the use of semiconductor materials. A test set was developed which enabled the thermoelectric device to be tested at pressures down to .0001 mm Hg. A prototype two stage cooler was designed

and tested. Its performance confirmed the basic calculations and has allowed the final three stage design to be completed. In design optimization studies the performance of cascaded devices was treated. A Dewar flask for the detector has been designed. Techniques for reducing junction resistance of thermoelectric devices were studied. The design of the cooler power supply was chosen.

3112
Norwood, M. H. A COMPARISON OF THEORY AND EXPERIMENT FOR A THERMOELECTRIC COOLER. J. Appl. Phys., 32: 2559-2563, figs., Dec., 1961.

The performance of single-stage Peltier thermocouples was calculated using the experimentally measured values of thermoelectric power, electrical resistivity, and thermal conductivity as functions of temperature. These calculations were made by solving numerically the differential equation for the temperature distributions in the thermoelements. The boundary conditions were the hot junction temperature and the heat flow at the cold junction. The calculated behavior of the thermocouples agreed well with that calculated from the material properties. The effect of temperature variations of the material properties on thermocouple performance was studied by comparing exact calculations with calculations involving one temperature-averaged constant material property. This type of calculation showed that the Thomson effect caused about 4°K of the maximum ΔT of 66°K for one couple studied. The temperature variation of resistivity was found to be the major cause of disagreement between exact calculations and the simpler theory (Ioffe equation).

3113
Ota, Akira, and others. THERMOELECTRIC COOLING OF POWER TRANSISTORS. J. Appl. Phys. (Japan), 29:375-377, June 1960.

The thermoelectric cooling is recommendable (1) when the transistor has to be placed in a limited space, (2) when the transistor noise is to be lowered. Thermal resistance θ of transistor is determined by the shape of the cooling device: it does not vary with the power input for cooling. (Japan Sci. Rev. Mech. & Elec. 7:1240, 1960).

3114
Parrott, J. E. and Penn, A. W. THE DESIGN THEORY OF THERMOELECTRIC COOLING ELEMENTS AND UNITS. Solid-State Electron., 3:91-99, Sept., 1961.

The relationship between refrigerating capacity per unit volume and coefficient of performance is examined for a single-stage unit.

3115
Reich, A. D., Arai, T., and Madigan, J. R. TRANSIENT EFFECTS IN PELTIER COOLERS. J. Appl. Phys., 32:2493-2494, Nov., 1961.

Points out the results of two previous papers on transient effects in Peltier coolers which are consequences of the restrictive assumptions of the model used. Some errors occuring in the previous papers are corrected. (Sci. Abs. 65A:149, Jan., 1962).

3116
Stubstad, W. R. THE APPLICATION OF THERMOELECTRIC SPOT COOLING TO ELECTRONIC EQUIPMENT. Inst. Radio Engrs. Trans. PEP-5:22-27, figs., Dec. 1961.

This report includes information on the thermal and mechanical evaluations of a spot cooled along with a discussion of the applications of spot cooling to electronic equipment. Also appears in IRE International Convention Record-See entry no. 2079.

3117
Suge, Yoshio and Aoki, Masaharu. THERMOELECTRIC COOLING BY BISMUTH-TELLURIDE THERMOJUNCTIONS. 3. COOLING EXPERIMENT. J. Appl. Phys. (Japan), 28:85-87, Feb. 1959.

Cooling effects of thermojunctions composed of p-and n-type Bi_2Te_3 is studied. The temperature of the cold junction is measured in vacuum as a function of the hot-junction temperature. Experimental results show fairly good agreement with what is predicted by a simple theory. A temperature difference of 67 deg is obtained at a mean temperature of 17°C. (Japan Sci. Rev. Mech. & Elec. 6:80, 1959).

3118
Swanson, B. W. and Somers, E. V. REFRIGERATOR HEAT LEAK FOR SANDWICHED THERMOELECTRIC ELEMENTS. J. Heat Transfer, 1:102-104, Feb. 1961.

It has been shown that the insulation heat leak for a thermoelectric refrigeration model, using thermoelectric-copper columns, can greatly exceed that leak computed on a simple one-dimensional heat-flow basis. The ratio of these two heat leaks has been evaluated analytically for a reasonable model, and its variation is represented in graphical form suitable for thermal design computations of thermoelectric refrigerating devices. It is recognized that the results can also be used for thermal losses in thermoelectric power generating devices.

3119
Texaco Experiment, Inc., Richmond, Va. THE USE OF THERMOELECTRIC MATERIALS IN ELECTRICAL INITIATORS, Final Report, by H. B. Forney, J. C. Wendall, and L. E. Line. 30p., Oct. 31, 1961. (Rept. EXP-342) (TP-183) (Contract N-178-7736).

Study of the feasibility of using thermoelectric heating in the design of a squib that provides some protection against rf radiation.

3120
THERMOELECTRIC COOLING. Elec. Times 136:615-616, 1959.

General review. Article with same title appears in Electronic Eng., 31:690-692, 1959.

3121
Trombe, Felix and Foex Marc. SUR LA PRODUCTION DE FROID A L'AIDE DU RAYONNEMENT SOLAIRE (ON REFRIGERATION BY SOLAR ENERGY). Acad. Sci. Paris. Compt. Rend., 242:1000-1003, 1956.

In French. Description of prototype of a new refrigerating machine of high efficiency coupled with a fixed east-west parabolic-cylinder mirror of 1.5 square meters.

3122
Uemura, Kin-ichi. CASCADE THERMOELECTRIC COOLING. J. Appl. Phys. (Japan) 29:377-383, June 1960.

Cooling by cascades of two and three stages of P-and N-type Bi_2Te_3 has been devised for obtaining deep temperature drop practically available. Experimental results are given with regard to maximum temperature drop and available cooling at various cascade ratios, i.e. ratio of the number of elements in upper/lower stages. Large temperature drop can be obtained with the cascade ratio of about 1:20; it falls rapidly as the number of lower stage elements is reduced. The absorbed heat increases linearly with the decrease in temperature difference at the same rate as in the case of single stage cooling. The temperature difference depends upon the hot junction temperature, hence four or more stage cascades will be but a vain elaboration. (Japan Sci. Rev. Mech. & Elec. 7:1243, 1960).

3123
Uemura, Kin-ichi. THERMOELECTRIC REFRIGERATION. J. Appl. Phys. (Japan), 29:389-395, June 1960.

Deals with the analogy between thermoelectric cooling and compression refrigerator system: theoretical consideration about the thermoelectric refrigeration in general: design of an experimental refriggerator, observed value of its cooling capacity with its theoretical treatment. The experimental refrigerator is of 35 ℓ capacity with polystylene sheet lining and foamed polystylene wall insulation. The cooling system, placed in the rear of the compartment, consists of two single-stage thermoelectric panels, each with 42 couples in series assembled and set in polyester resin. Aluminium heat absorber and water-cooled heat dissipator are electrically insulated from, but thermally conductive to, cold and hot sides of the panels to obtain good heat transfer. With the compartment empty and the ambient temperature of 30°C, interior air temperature dropped by 34 deg. in 3 hours. Observed cooling effect, which involves the heat absorbed by the system and the heat leakage through walls at steady state, was in good agreement with the calculated pumping effect of the system. (Japan Sci. Rev. Mech. & Elec., 7:1245, 1960).

3124
Uemura, Kin-ichi, Omuro, Yuzo, and Matsuhashi, Y. A THERMOELECTRIC THERMOSTAT. J. Appl. Phys. (Japan), 29:383-388, June 1960.

A thermally insulated 25 litre chamber is cooled by a thermoelectric system consisting of 42 couples connected in series and mounted in two rows on rear and two side walls. The figure of merit of the thermoelement is $Z = 1.81 \times 10^{-3}$/deg. The heat evolved at the hot junctions is dissipated by natural convection. For obtaining good heat exchange at the junctions, radiators made of copper are soldered directly to the hot and cold sides of the elements. A long cylindrical leg of copper is inserted between the cold fin and the cold side of the element, thus making the thermal insulating wall much thicker. With D.C. power consumption of 60 watts a temperature drop of 30 deg was obtained, and with 120 watts 33.6 deg from the ambient temperature of 30°C. Steady conditions was set up in 4 hours. (Japan Sci. Rev. Mech. & Elec., 7:1244, 1960).

3125

Uenohara, M. and Wolfe, R. PARAMETRIC AMPLIFIER WITH THERMOELECTRIC REFRIGERATION. Inst. Radio Engrs. Trans., ED-8:521-524, illus., Nov. 1961.

The noise figure of a variable-capacitance parametric amplifier can be greatly improved by refrigerating the diode. A thermoelectric refrigerator can be used for this purpose without losing the advantage of system simplicity. A two-stage thermoelectric refrigerator has been built into a 6-Gc parametric amplifier. With no load this refrigerator has produced a temperature difference of 101°C below room temperature. In the amplifier it cooled the diode to 213°K. The effective noise temperature of the amplifier was reduced from 170°K when the GaAs diode was at room temperature to 108°K when the diode was cooled at 213°K. The design, construction, and characteristics of the amplifier and the thermoelectric refrigerator are described.

3126

Weichel, Mogens. PELTIER-KØLING. (PELTIER COOLING). Kulde 13:13-18, Apr.; 28-35, figs., June 1959.

In Danish. The article comprises the complete theory for cooling (heat pumping) by means of thermoelectric materials, as seen from an engineers viewpoint. From the basic physical equations (Seebeck effect, Peltier effect, Kelvin effect, heat transmission, Ohm's law, Joule's law) is derived terms for the cooling load, current, voltage, and power. It is shown to be a good approximation (in respect to the Kelvin effect) using the mean value of the Seebeck coefficient for the temperature range dealt with. The terms are optimized in respect to material parameters; to COP; to cooling load; and to temperature drop. Some considerations for two-stage design are mentioned, i.e., COP; inter-temperature; and the depths of the stages. The last section of the article outlines problems from the solid-state physics involved.

3127

Westinghouse Electric Corp. New Products Engineering Department, Pittsburgh, Pa. DESIGN OF MODEL OF A THERMOELECTRIC AIR CONDITIONING SYSTEM FOR SUBMARINES, Final Report, by E. W. Frantti. 75p., May 1961. (Rept. 9161-01208-208(1)) (Contract NObs-77095) (AD-269 775).

This final report describes a thermoelectric heating and cooling module constructed for installation in a water-to-water air conditioning system, aboard a submarine. The module, weighing 50 pounds, has a cooling rating of 2550 BTU/hr, at a coefficient of performance of 0.75 and an operating current of 35 amperes dc.

3128

Westinghouse Electric Corp., Youngwood, Pa. THERMOELECTRIC TEMPERATURE CONTROL FOR QUARTZ CRYSTALS AND CRYSTAL OSCILLATORS, by T. D. Merrits, J. C. Taylor, et al. 2 issues, Jly., Oct., 1961. (Quart. Repts. 1, 2) (Contract DA36-039-sc-87190) (AD-264 529, AD-270 614).

An approximate design procedure on a thermoelectric single couple is presented using average values of material parameters. Emphasis is placed on which of the variables, T_h - hot side temperature, T_c - cold side temperature and Q - net heat pumping rate, may be specified. It is found that specification of all three determines the area/length ratio of the couples when the average material parameters are known. An experimental analysis of the heat pumping performance for a single stage thermoelectric chamber utilizing a pyrex dewar flask as the inner-core enclosure is described. It is found that by utilizing a pyrex dewar flask heat leak is considerably reduced, thus, small size, less number of couples and lower input power can be realized for a chamber design.

3129
Whirlpool Corp., Research Laboratories, St. Joseph, Mich.
LIFE TEST OF THERMOELECTRIC MODULES CONSTRUCTED UNDER PHASE II, by R. L. Eichhorn, R. G. Sickert, et al. 4 issues, Feb. 8, Feb. 28, May 24, Jly. 26, 1961. (Prog. Repts. 17, 18, 19, 20) (Contract NObs-77128).

The life test was discontinued after 5-1/2 months. Five of the original 12 modules had increases in resistance of 10% or less, which is regarded as satisfactory. Two of the modules failed. Work on this contract is completed.

3130
Whirlpool Corp. Research Laboratories, St. Joseph, Mich.
THERMOELECTRIC TEMPERATURE CONTROL IN AN/URQ-9 FREQUENCY STANDARD, by R. G. Sickert and A. F. Martz. 2 issues, Oct. 20, 1961, Jan. 22, 1962. (Interim Devlpmt. Repts. 2, 3) (Contract NObsr-85314) (AD-266 044; AD-271 413).

Presented are highlights of oven construction, thermoelectric device construction, component placement and the results of preliminary performance tests.

3. Thermocouples

3131
Baker, H. D., Ryder, E. A. and Baker, N. H. TEMPERATURE MEASUREMENT IN ENGINEERING. v. 1, New York, Wiley, 1953.

This first of a two volume work deals primarily with thermocouple technique.

3132
Bansal, T. D. COPPER-ADVANCE THERMOCOUPLES IN THE TEMPERATURE RANGE 0-100°C. J. Sci. Indus. Res., 20D: 23-24, Jan. 1962.

The limitations of using copper-Advance thermocouples have been studied in the temperature range 0-100°C. The thermo-emf (e) in microvolts, at different temperatures (t), when one junction is at 0°C, is fairly well represented by the expression $e = bt + ct^2$, where $b = 36 \pm 1$ and $c = 0.043$. For commercial applications it is enough to calibrate such couples at one point only; for higher precision calibration at two points is necessary. Suitable tables for practical computation of temperature from thermo-emf, and vice versa, can be compiled from this relation.

3133
Brownwood, J. B. THERMOCOUPLE COMPENSATING CIRCUIT DESIGN. Electron. 35:98, 100, diags., Jan. 5, 1962.

Temperature-compensating circuit permits high-accuracy temperature measurements in missile flight testing. The circuit eliminates the need for controlling temperature of one of the two junctions in a thermocouple. It is practical for use in missiles, providing fast response in the rapidly changing environment and consuming limited power.

The temperature-compensating circuit described provides a voltage to compensate cold junction emf.

3134
Chysky, J. TEMPERATURE MEASUREMENT BY THERMOCOUPLES. Zdravotni. Tech. a Vzduchotech., 3:158-171, 1960.

In Russian. Not examined. Data are given on the electrical and thermal properties of thermocouples, their emf, the methods of welding, the relation between temperature of the junction and a contact with thick and thin walls, immersion of a liquid, securing in a groove on the surface of a solid body and the relation between thermocouple readings and other conditions of their use. (Abs. J. Metall. B, no. 4:73, 1961).

3135
Cibrowski, F. THE EFFECT OF NON-HOMOGENEOUS THERMOCOUPLE ELEMENTS ON THE ACCURACY OF NiCr-Ni THERMOCOUPLES. Pomiary Automatyka Kontrola no. 2, p. 64-67, Feb. 1960.

In Russian. The problem of non-homogeneous distribution of alloy elements in thermocouple wires and its influence on temperature measurement in the case of two typical thermocouples are discussed. Dahl's investigations are reviewed and conclusions from investigations into the nature of the change of NiCr-Ni thermoelectric properties at high operating temperature are given. The importance and purpose of having a constant immersion depth for a thermocouple at its operating

point, as well as making "in situ" checks to obtain current results are emphasized. Checks on thermocouples carried out in a laboratory where the temperature distribution along thermocouple wires is of necessity different from that at its operating point in a given plant do not necessarily represent the true properties of the tested equipment. (Fuel Abs. & Current Titles 2:5419, Aug., 1961).

3136
Dietze, Hans-Joachim. TEMPERATURE MEASUREMENT ON IRON AND STEEL MELTS. Z. Messen Steuern Regeln 4: 339-344, Aug. 1961.

In German. Review of temperature measurements of Fe and steel melts by optical pyrometers and thermocouples in terms of thermovoltage-temperature relations for various PtRh-base thermocouples. Survey of lifetime of thermocouples and measuring and automation registration devices. (ASM Rev. Metal Lit. 19:49, Jan. 1962).

3137
General Electric Co. Instrument Department, West Lynn, Mass.
A JET ENGINE THERMOCOUPLE SYSTEM FOR MEASURING TEMPERATURES UP TO 2300°F, by M. E. Ihnat. 125p., Oct. 1958. (WADC-TR-57-744) (Contract AF33(600)-32302).

A reliable thermocouple temperature sensing system for aircraft jet engines having an operating temperature range of 1800°F(982°C) to 2300°F(1260°C) has been developed. The system is unique in that it uses a thermoelement combination of palladium and platinum 15% iridium. Provisions are also made for matching lead wires up to ambient temperatures in the 1300 to 1500°F(704° to 816°C) temperature range. The system has been shown to be reliable over the specified temperature range for a 400 hour period. (Nuclear Sci. Abs. 13:14529, Aug. 31, 1959).

3138
Gregory, Edwin. THE HEAT TREATMENT OF STEEL-BASE-METAL THERMOCOUPLES. Edgar Allen News 40:207-208, Sept. 1961.

Properties of combinations of Cu-Ni alloys with wires of Cu, Ag, Ni or Fe, with data given for temperature ranges and resistances. Prevention of oxidation of thermocouple wires at high temperatures using a protective sheath. Method of calibrating thermocouples and converting emf. values into temperature. (ASM Rev. Metal Lit. 18:22, Dec. 1961).

3139
Karpov, I. V. THE POSSIBILITY OF MEASURING THE TEMPERATURE OF LIQUID STEEL AND MOLTEN FLUX BY A PROTECTED LOW-TEMPERATURE THERMOCOUPLE. In Symposium: Metallurgia, no. 2, Leningrad, Sudpromgiz. p. 126-135, 1959.

In Russian. At the present time either Pt/Pt-Rh or W-Mo immersion thermocouples, operating under very severe conditions are used to measure the temp. of liq. steel. It is proposed to replace this method, in which the working end of the thermocouple is brought to the temp. of the medium t_m, by another thermoelectric method, in which the rate of change of temp. in the centre t_c of a cylindrical body of low thermal conductivity, immersed in the medium to be measured, serves as the criterion of the deg. of heating of the molten medium. A low-temperature thermocouple(LT), of the chromel-alumel type, can be used. The measurement results obtained by means of LT differ from the check measurements of ordinary W-Mo immersion thermocouples by not more than 25°. (Abs. J. Metall. USSR no. 12(Part B):39, 1960).

3140
Kirschning, H. J., Hochstrate, Emil, and Rodrian, Hermann. MEASUREMENT OF THE VAULT TEMPERATURE OF OPEN-HEARTH FURNACES THERMOELECTRICALLY. Arch. Eisenhüttenw., 28:611-614, 1957.

In German. Describes a method by using a Pt-Rh element with a BeO protective tube which is introduced through a hole in the vault. (Chem. Abs. 52:1880, 1958).

3141
Kisly, P. S. and Samsonov, G. V. HIGH-TEMPERATURE THERMOCOUPLES USING SEMICONDUCTORS. Planseeb. Pulvermetall. 8:200-206, 1961.

In German. Couples between semiconductors such as B_4C and $CrSi_2$ on the one hand and carbides or borides on the other,

have high thermoelectric-power values which a temperature and arc-resistant to many aggressive media. Thermocouples were constructed with an outer tube of $MoSi_2$ or various carbides or borides of Ti or Zr and a central rod of B-saturated graphite. The former is suitable for oxidizing conditions, the others for vacuum, reducing, or inert atmospheres. Outer sheaths of borides withstand molten pig Fe, steel, and brass. Improved mechanical strength is achieved in a Mo sheath treated both inside and out to form a silicide layer. (Metall. Abs. 29:390, 1961). (Translation available in U. K. A. E. A. Atomic Energy Research Establishment, Harwell, Birks. AERE Trans. 874).

3142
Kisly, P. S. et al. THERMOELECTRIC CHARACTERISTICS OF HIGH-TEMPERATURE THERMOCOUPLES WITH REFRACTORY ELECTRODES. Izmeritel. Tekh. no. 5:21-23, May 1961.

In Russian. Transl. in Meas. Tech. no. 5, p. 366-369, May 1961.

Thermocouples made of high-melting compounds of transition metals (carbides, borides, nitrides and silicides) make it possible to measure temperatures under more exacting conditions and have a higher thermal-emf than the existing metal high-temperature thermocouples; moreover, they are as accurate as metal thermocouples. Changes in the thermal-emf of high-melting thermocouples decrease with a rising operation time, thus making it advisable and necessary to submit them to stabilitizing annealing, by using thermocouple materials with close chemical tolerances, standardizing their production and annealing, it becomes possible to produce thermocouples with standard calibrations. The results published in this article are not final, since they were obtained on several tens of thermocouples made under laboratory conditions.

3143
Lachman, J. C. THERMOCOUPLES FOR ULTRA-HIGH TEMPERATURES. Metal Prog., 80:73-76, 1961.

Three new thermocouples were developed for measuring temperature in the range 3000-5000°F(1650-2760°C). The Pt-30% Rh/Pt-6% Rh and the Ir/Ir-Rh thermocouples can be used up to 3700°F(2040°C) and the W/W-26% Re thermocouple is useful up to 4200°F (2300°C). The last could be used to 5000°F with better heat insulators. (Metall. Abs. 29:659, Mar. 1962).

3144
Lacroix, R. PLATINUM-RHODIUM-PLATINUM THERMOCOUPLES. Pomiary Automatyka Kontrola, 6:334-346, 1960.

In Polish. The heterogeneity of the thermometric characteristics of thermocouples (T) and the possibility of obtaining T with any characteristics are discussed. Tables give a comparison of the characteristics of Pt/10Pt-Rh and Pt/13Pt-Rh thermocouples, used by the following organizations: National Bureau of Standards (U. S. A.); National Physical Laboratory (England); Physikalische Technische Reichsanstalt (W. Germany) and the Kamerling Onnes Laboratory(Holland). An exhaustive determination of the following 3 concepts is given: the basic temperature scale, the international scale, and state thermometric characteristics. The international scale envisages the use of Pt/10Pt-Rh T for temperature measurements within limits of 630.5-1063° and indicates the conditions which T must meet, methods of calibration, and the use of interpolational formulae in order that the temperature measured should not differ from the thermodynamic temperature by more than 0.1°. For practical purposes the region of utilization of T is raised > 1063°. In some countries the characteristics of Pt/13Pt-Rh T have been developed within the limits of normalization. These T have no advantages over T containing 10% Rh. The differences between normalized characteristics are caused primarily by the different Rh contents in the alloy and depend to a lesser deg. on the purity of its components and the coefficient in the interpolational equation. (Abs. J. Metall. no. 5B:101, 1961).

3145
Lieneweg, F. LAG OF THE READINGS OF THERMOELECTRIC PYROMETERS AND ERRORS OCCURRING AS A RESULT OF HEAT DISSIPATION. Pomiary Automatyka Kontrola 8:299-301, 1960.

In Polish. For the metrological characteristics of temperature measurement it is not sufficient to know the accuracy of the thermocouple, because the errors arising as a result of heat transfer from the body

investigated and the dissipation of the heat along the gauge must also be known. The determination of these errors is difficult because they depend on the nature and design of the sensitive element, and the nature of the centre of the gauge, the temperature of which is measured. The dissipation of heat along the gauge leads to errors, as a result of which the measured temperature is below the true value. The manner of dissipation of heat by gauge also influences its dynamic properties. Since the centre of the gauge is detachable the device can be made sufficiently sensitive to temperature variation by appropriate design of the gauge. The rate of reaction of a thermocouple to temperature variation is of great importance for solving problems of temperature control. Calculations are given of errors arising as a result of heat dissipation. (Abs. J. Metall. no. 3B:56, 1961).

3146

Metenin, V.I. EXPERIMENTAL INVESTIGATION OF THE THERMAL INERTIA OF A THERMOCOUPLE OF TYPE TE-11. Trudi Kuibyshevsk. Aviats. In-ta, no. 5: 71-83, 1958. Ref. Zh. Mekh. no. 1, 1960, Rev. 904.

In Russian. An investigation was carried out as stated in the title. The work of this type of thermocouple is based on the agitation of the gas in the internal cavity of the screen. The investigation was carried out in a flow of air with velocities of $\simeq$60 m/sec. It was established that in order to reduce the constants of thermal inertia it is essential to reduce the diameter of the electrodes and to increase the area of the outlet opening of the thermocouple's screen. It was shown that thermocouples of the type being investigated exhibit weak sensitivity to orientation in the limits of $0 \pm 20^{\circ}$. At large angles of attack the time constant increases. (Appl. Mech. Revs. 15: 1005, Feb. 1962).

3147

Miyatani, H., Tanabe, K. et al. HIGH TEMPERATURE DETERIORATION OF PLATINUM-TO-PLATINUM 13%-RHODIUM THERMOCOUPLE IN TUNNEL KILN. Electrotech. Lab. Bull. (Tokyo), 24: 299-305, Apr. 1960.

In Japanese. Deterioration was examined by measuring changes in thermoelectric force at temperatures from 1000° to 1300°C for periods up to 8000 hr. It is shown that decrease in thermo emf becomes greater at temperatures >.1200°C, the Pt wire deteriorates more than the Pt-13% Rh wire, and the initial rate of deterioration is high, but decreases with time. (Sci. Abs. 64B:4564, Aug., 1961).

3148

Obrowski, W. THERMOELEMENTS. Arch. Tech. Messen, p. 183-186, Aug., 1961.

In German. Considers thermocouples made from non-precious metals, including standarized and non-standarized types. Tabulated data are given for general commercial thermocouples for the temperature-voltage characteristics. Methods of construction and permissible tolerances are detailed. (Index Aero. 17:46, Nov., 1961).

3149

Okada, Kiyoshi, Ishikawa, Masumi, and Ueda, Isamu. RESULTS OF THE INTERLABORATORY COMPARISON OF THERMOCOUPLES AT THE Ag POINT. Electrotech. Lab. Bull. (Tokyo), 23:45-50, Jan. 1959.

As one of three laboratories taking part in an interlaboratory comparison of the International Temperature Scale realized in Japan, the Electrotechnical Laboratory carried out measurements of the emf of 4 standard thermocouples (platinum and platinum-10% rhodium alloy, 3 of which being annealed at 1100°C for 1 hour and one at 1350°C for 1 hour) at the silver point. The weight of Ag-ingot was about 900 g. Changes in the emf of the thermocouples at the fixed point due to 1 cm changes in depth of immersion remained within 0.5 μV, and the duration of the equilibrium was kept about 20 minutes long. The reproducibility of temperature for each thermocouple was less than 0.04°C. The apparatus and results of the measurements are also described. (Japan Sci. Rev. Mech. & Elec. 6:82, 1959).

3150

Perrot, Marcel and Peri, Georges. ON CERTAIN THERMOCOUPLES. J. Phys. et Radium 17:35S-36S, June 1956.

In French. Thermo-emf's generated by couples of metal/oxide of the same metal/metal are discussed. PbO_2, Al_2O_3, ThO_2 yields a negative hot junction. If a

drop of distilled water is added to the oxide, the sense of the emf is reversed.

3151
Powell, R. L. and Caywood, L. P., Jr. THERMOCOUPLE THERMOMETRY. Prog. Cryogenic Eng. Conf., p. 38A, Aug. 1961.

A report on the calibration of three thermocouples is given: alumel vs chromel (ISA type KN-KP); constantan vs iron (ISA type YN-YP). In addition to the actual detailed calibration tables, there is a quantitative discussion of the thermoelectric inhomogeneities caused by variations between different lots of wire. Fixed point calibrations are also given for a commercial thermocouple, gold-palladium vs platinum-iridium, and a specially prepared alloy system of silver-gold vs copper. None of the commercial thermocouple systems prove to be as useful at low temperatues as either gold-cobalt or constantan vs copper. (Solid-State Abs. 2:11, 222, 1961).

3152
Rudnicki, A. A. NOBLE METAL THERMOCOUPLES FOR MEASURING HIGH TEMPERATURES. Pomiary Automatyka Kontrola 6:145-146, 1960.

In Polish. The characteristics of thermocouples of noble metals and the variation of the readings of different thermocouples are given on the basis of literature data and investigations. It is indicated that extensive investigations of various materials for thermocouples showed that the continued, invariable and reliable functioning of the latter at temperature in air is only possible if they are made of noble metals. Thermocouples of Pt and Rh alloys are reliable. Their durability increases with an increase in the Rh content in the alloy. Ceramic insulation plays a considerable role in obtaining constant thermometric characteristics. The use of ceramics containing SiO_2 is not recommended because the reduced Si forms alloys with the materials of the thermocouple. A ceramic insulation of Al oxides gives good results. A reducing atmosphere cannot be employed for the measurement of high temperatures for either noble metal or ordinary alloys. (Abs. J. Metall. (Pt. B) no. 1, 104, 1961).

3153
Sagoschen, J. TEMPERATURE MEASUREMENT WITH PLATINUM-METAL THERMOCOUPLES. Metall. 15:34-40, Jan. 1961.

In German. Pt-PtRh thermocouples of varying composition for temperature measurements up to 1500°C. Calibration of thermocouples. Properties such as thermoforce and stability. Use of platinum-metal (Ir, Rh, Pt, Ru) based alloys containing Re, Ru, W or Mo in thermocouples for temperature measurement above 1500°C. (ASM Rev. Met. Lit. 18:6-x, Mar. 1961).

3154
Suzuki, Mitsuru and Mizuguchi, Kanji. THERMOCOUPLES USEFUL AT VERY LOW TEMPERATURES. Electrotech. Lab. Bull. (Tokyo), 23:488-490, Jly. 1959.

Temperature versus thermo-emf are measured for thermocouples composed of: Au-Co (2.1 atomic %)/Cu, Au-Co (2.1 atomic %)/Chromel, and constantan/Cu between 2° and 60°K using a constant-volume helium gas thermometer as temperature standard. The Au-Co/chromel thermocouple is more suitable for low temperatures than Au-Co/Cu, which is commonly used for liquid-helium and room temperatures. (Japan Sci. Rev. 6(3): 2660, June 1960).

3155
Svede-Shvets, N. I. and Pridamtsev, M. V. THERMOCOUPLE FOR SHORT-DURATION TEMPERATURE MEASUREMENTS REACHING 2,300°. In Conference on Experimental Technique and Methods in High Temperature Investigations, 1956, p. 83-129, Moscow, 1959.

Translation of Russian conference papers.

Studies were made of thermocouples for short-duration measurements reaching 2,300°. The difference of the potentials arising at the ends of an unevenly heated homogeneous conductor was used for temperature measurements. A thermocouple designed for short-duration measurements of liquid steel temperatures is described. Tungsten was used in the positive thermoelectrode and an alloy of molybdenum with aluminum was the negative. The thermocouple made it possible to measure temperatures in the 100 to 2,300°C range, developing during this a maximum thermal emf of the order of 20 mv. The smooth gain of its thermal emf as the temperature rose became

linear in dependence on reaching 1,000°C. The thermocouple, after prolonged annealing of the molybdenum thermoelectrode, assures stable temperature measurements up to 2,000° in a vacuum and argon for more than 100 hours as well as those of short-duration. Numerous immersions of the non-renewable hot junction of the thermocouple into a liquid metal with the use of replaceable quartz caps did not cause a decrease in thermal emf. (Nuclear Sci. Abs. 15:22466, 1961).

3156
Tomis, L. DEVICES FOR MEASURING THERMAL CURRENTS IN METALLURGICAL FURNACES. Hutn. Listy 14:947-950, 1959.

In Hungarian. The thermal battery, made from SiC and Cu, ensures an emf of 0.3 mc/deg. The relations between the emf of 0.3 mc/deg. The relations between the emf of the Cu-silit element and the value of calibrated against chrome-magnesite brick heated in an electric furnace, the temperature of which is controlled by a Pt/Pt-Rh thermocouple, or against the radiation of an electric spiral, the thermal capacity of which is known. (Abs. J. Met. USSR no. 9 (Part B):92, 1960).

3157
U. S. Air Force Wright Air Development Division. Flight and Engineering Test Division, Wright-Patterson Air Force Base, Ohio.
COMMON PARALLEL THERMOCOUPLES FOR AVERAGE TEMPERATURE MEASUREMENT, by B. B. Boggs. 47p., Nov. 1960. (WADD Tech. Rept. 60-650) (AD-255 753).

The report describes the use of common parallel thermocouple circuits for temperature control in thermal simulation. Iron-constantan thermocouples were welded directly to the basic metal being heated. Structural tests at elevated temperatures show that thermocouples connected into parallel electrical circuits and grounded to a common metal sheet give the same temperature measurements as separated thermocouples connected into a parallel circuit. This method is applicable to any test situation requiring average temperatures. (Res. Repts. 36:S-70, Nov. 20, 1961).

III. THERMIONIC EMISSION

3158
Dietrich, R. THERMOELECTRIC PUMPS FOR LIQUID METALS. Ver. Deut. Ing. Z., 103:17-19, Jan., 1961.

In German. A thermoelectric d c pump is described which can be used in the event of a breakdown of the main pump of a sodium-cooled reactor so that heat produced by the fission products - after the reactor has been automatically switched off - can be removed without using an external electricity supply.

3159
Ershov, V. N. THERMOELECTRIC HYGROMETER. Zavodskaia Lab., 27: 212-213, 1961.

In Russian. English summary in Chem. Abs. 55:24130, Nov. 27, 1961.

3160
Korsunskii, M. I., Zaichik, R. P., and Lembik, L. N. EXTENSION OF THE RANGE FOR MEASURING VACUUM BY THE THERMOELECTRICAL METHOD. Pribori i Tekh. Eksp. no. 3, p. 114-118, May/June 1961.

In Russian. Transl. in Instr. & Exp. Tech. no. 3, p. 527-530, figs., Dec. 1961.

The thermoelectrical method of measuring vacuum is based on the dependence of the thermal conductivity of the gas on pressure. By reducing the thermal conductivity of the manometer and its radiation losses, the relative importance of the main working processes of the method -- the heat transfer through the gaseous medium -- can be increased. The thermal conductivity of the manometer was reduced by the use of a thin-layer heater and thermopiles. The radiation is reduced by spraying the heater with two metals and cooling it by using the Peltier effect. The work shows that the application of thin-layer manometers and the utilization of the Peltier effect make possible an increase of the range of the thermoelectrical method into the high vacuum region, i. e. to about 5 to 6 x 10^{-6} mm Hg.

3161
Kumar, K. S. and Chowdhury, A. P./ A PHOTOELECTRIC TEMPERATURE

CONTROLLER. NML Tech. J. 3:29-31, Aug. 1961.

A photoelectric temperature controller is described which uses a thermocouple as the sensing element. The error signal operates a mirror galvanometer. The light from the galvanometer falls on a photocell and the photocurrent is amplified by a differential d.c. amplifier operating a relay, which controls the furnace current. (Battelle Tech. Rev. 11:67a, Feb. 1962).

3162
Ramzaev, P.V., Negurei, A.P., and Bichkov, V.P. DETERMINATION OF THE BASAL METABOLIC RATE BY THE THERMO-ELECTRIC METHOD. Problemy Endokrinol. i Gormonoterap. 5:80-87, 1959.

In Russian. Transl. 61-23899 available from OTS or SLA. JPRS:9616.

A calorimeter consisting of a combination of eleven sensors to be attached to specified points on the body, together with a series of thermocouples, is described. (Tech. Trans. 6:559, Oct. 31, 1961).

3163
Semenkovich, S.A., Kolomoets, L.A., and Kolomoets, N.V. CRYSTALLIZATION OF Bi, Te, AND Bi_2Te_3 BY MEANS OF THE PELTIER EFFECT. Fiz. Tverdogo Tela 3:1597-1600, May 1961.

In Russian. Transl. in Soviet Phys. Solid State 3:1159-1161, Nov., 1961.

The motion of the interface between solid and liquid phases under the action of direct current flowing along the normal to this interface was observed in a specially-constructed apparatus. Peltier coefficients were determined for Bi, Te, and Bi_2Te_3 from the velocity of the interface under nearly isothermal conditions. The stabilization of the crystallization front is explained, and certain possibilities for utilizing it are pointed out.

3164
Tomlinson, C. THERMOELECTRIC MICRO DETERMINATION OF MOLECULAR WEIGHT. Mikrochim. Acta p. 457-466, 1951.

(In English). An apparatus using matched thermistors is described which gave results accurate to within 2% in the range 100-700.

A. General Information

3165
Atomics International, Division of North American Aviation, Inc., Canoga Park, Calif. FIRST SUMMARY REPORT OF BASIC RESEARCH IN THERMIONIC ENERGY CONVERSION PROCESSES, by R.L. Carter and R.L. McKission. 231p., Nov. 15, 1961. (AI-6799) (Contract Nonr 3192(00)).

Incentives for achieving a thermionic nuclear power plant for naval applications are briefly reviewed, and the associated thermionic energy conversion processes chosen for basic study are qualified and summarized. The results and status of these basic investigations are reported in a symposium of independent papers.

3166
General Electric Co., Research Laboratories, Schenectady, N.Y.
A TITANIUM MATCHING SILICA-FREE CERAMIC, by J.G. Leschen. 22p., Mar. 1961. (Sci. Rept. 7) (Contract AF 19-(604)-5472).

The future of the ceramic in vacuum devices using oxide cathodes is uncertain, according to statements made resulting from efforts to develop a satisfactory ceramic. It is also stated, however, that the material can be used in devices with less sensitive cathodes, and plans are afoot to test it in a cesium vapor thermionic converter.

3167
Harrowell, R.V. THERMIONIC CONVERSION OF HEAT TO ELECTRICITY. Nature 192: 611-612, Nov. 18, 1961.

Brief summaries are given of papers presented at a symposium on the thermionic generation of electricity held at Bankside House, London, on May 11, 1961 under the auspices of the Central Electricity Generating Board.

3168
Huber, H. and Bensimon, J. SUR LA CONVERSION DIRECTE DE CHALEUR EN ENERGIE ELECTRIQUE PAR LA DIODE THERMOELECTRONIQUE. (ON THE

DIRECT CONVERSION OF HEAT TO ELECTRICAL ENERGY BY THE THERMO-ELECTRONIC DIODE). Ann. Radioelec., 16:155-202, Apr. 1961.

In French. The behavior of the first type of convertor can be described quite rigorously, but the investigation of the second one still raises difficulties in respect of the behavior of the cesium plasma. After an introductory chapter which includes some general points on the distribution of the inter-electrode potential, a sketch is given in chapters 2 and 3 of the main aspects of the thermoelectronic conversion of heat into electricity, these two chapters ending in the evaluation of the power of conversion. Conversion efficiency is treated separately in chapter 4. The experimental results obtained or expected are summarized in chapter 5. The article concludes with an attempt to extract a few conclusions, in chapter 6, regarding the problems which remain to be dealt with, possible applications, and future performance. (Sci. Abs. 64B:6182, Nov. 1961).

3169
Jarvis, Theodore, THERMIONIC CONVERSION -- STATE OF THE ART. Inst. Radio Engrs. Trans. MIL-6:41-45, figs., Jan., 1962.

After a brief discussion of fundamental principles, a family tree of different types of thermionic converters is presented. A description of the materials problems is given. The paper concludes with projections of development and performance trends of the most important types of thermionic converters.

3170
Marquardt Corp., Van Nuys, Calif. THERMIONIC CONVERTER RESEARCH, by R. Laubenstein, W. Beyermann, et al. 2 issues, Sept., Dec. 1961. (Quart. Prog. Repts. 1, 2) (Contract DA36-039-sc-87217).

The study is directed toward improved knowledge of and new design concepts for thermionic converters capable of efficient operation at temperatures obtainable with conventional fossil fuels.

3171
Pidd, R. W. POWER CONVERSION: PLASMA METHODS. In Foundations of Future Electronics, p. 257-274, New York, McGraw-Hill, 1961.

The article brings together in a general way the various disciplines that have a bearing on the analysis of the cesium diode as a heat-to-electricity converter.

3172
SYMPOSIUM ON THERMIONIC POWER CONVERSION. Sun at Work, 6:11, Fourth Quarter, 1961.

A brief outline of the subjects to be covered in the joint technical socity-Department of Defense symposium at Colorado Springs, May 14-16, 1962.

3173
Wait, E. T. THE THERMIONIC ENERGY CONVERTER. Res. Appl. Indus. 15:75-80, Feb. 1962.

An explanation is given of the basic principles of the converter which transforms heat directly into electricity, by the phenomenon of thermionic emission. The dependence of the conversion efficiency on electrode materials and negative space charge in the diode is explained. Methods of reducing the space charge are described. Finally, applications as a small generator in satellites etc., and as a large generator in power stations are discussed.

3174
Welsh, J. A. and Kaye, Joseph. THERMIONICS. Indus. Res., 3:50-54, Oct. 1961.

The broad applications of thermionic converters as power supplies are discussed.

3175
Westinghouse Electric Corp., Pittsburgh, Pa. HEAT DIODE CONVERTER. 86p., illus., Aug. 20, 1961. (Interim Sci. Rept. 1) (Contract AF33(616)8262) (AD-265 360).

Included in contents are: Space charge limited currents in thermionic diodes at high cesium pressure; Potential distributions in high pressure cesium thermionic diodes; Thermionic diodes, Carnot efficiency, and anomalous Richardson constants; Theoretical efficiencies of thermionic diodes; Life testing of seals for thermionic diodes.

3176
Westinghouse Electric Corp. Electronic Tube Division, Elmira, N. Y. and Westinghouse

Electric Corp., Research Laboratories, Pittsburgh, Pa. FISSION HEAT DIODE CONVERTER, March 7, 1960 to April 30, 1961, by G.R. Feaster, M. Gottlieb and R.J. Zollweg. 64p., May 31, 1961. (ASD-TR-61-281) (Contract AF33(616)7198).

Thermionic conversion of fission heat using cesium vapor diodes offers promise as an electrical power source for space vehicles. Research and development work on cesium vapor diodes is reported, as well as a state-of-the-art survey and an extensive bibliography. Experimental and/or theoretical results are given in the following areas: effect of gas adsorption on the emission from cesiated tungsten; plasma oscillations; thermal conductivity of cesium vapor; electron scattering in cesium vapor; effect of varying cesium pressure, cathode temperature, and spacing in a cesium cell; construction techniques and materials problems. The use of plasma oscilations to generate alternating current is discussed and an analysis showing that the use of hybrid thermionic thermoelectric systems in space is not favorable is included. (Nuclear Sci. Abs. 16:3937, Feb. 15, 1962).

3177
Westinghouse Electric Corp., Pittsburgh, Pa. HEAT DIODE CONVERTER. 100p., illus., Nov. 20, 1961. (Interim Sci. Rept. 2) (Contract AF33(616)8262) (AD-268 286).

Contents: Thermionic diode currents in transverse magnetic fields; Fabrication of electron beams heated button-cathode cell; The lifetime and efficiency of a thermionic energy converter; The calculation of the efficiency of energy conversion by thermionic emission.

3178
Wright, D.A. A SURVEY OF PRESENT KNOWLEDGE OF THERMIONIC EMITTERS. Inst. Elec. Engrs. Proc. 100, Pt. III, 125-142, May 1953.

Reference is made in the text to 60 bibliographical items. In addition 10 items are cited as general references.

B. Theory

3179
Arifov, U.A., Raknimov, R. et al. PROBLEM ON THE PRESENCE OF POTENTIAL EMISSION OF ELECTRONS IN THE BOMBARDMENT OF METALS BY IONS OF INERT GASES [AND] ABOUT THE METHODS OF INVESTIGATING THE SECONDARY PROCESSES CAUSED BY IONS AT HIGH TEMPERATURE OF TARGETS IN THE PRESENCE OF THERMIONIC EMISSION. Akad. Nauk, Uzbek. SSR. Izvest. Ser. Fiz-Matem. Nauk. no. 5: 5-13, 15-22, 1958.

In Russian. Rough draft transl. no. MCL-301/1+2, available from OTS or SLA (AD-257 658).

Experiments confirmed the presence of potential emission of electrons during the bombardment of a metal under conditions such that the potential of ion ionization is greater than twice the work of the target yield. Results of V.G. Tel'kovskiy (Doklady Akad. Nauk SSSR 108:445, 1956 and Izvestiya Akad. Nauk SSSR Ser. Fiz. 20:179, 1956) that cast doubt on the existence of potential emission under these conditions were due to contaminations of the target surface with oil vapors during the thermal treatment. An improved method of double modulation is described that allows one to investigate separately the individual components of the secondary emission (i.e., the currents of scattered, evaporated, and diffused ions and thermal electrons) which emerge simultaneously during the bombardment by positive ions of pure metallic targets at 1300° to 2000°K in the presence of considerable thermionic emission. (Tech. Trans. 6:621, Oct. 31, 1961).

3180
Panchenkov, G.M. and Kolchin, A.M. THE ROLE OF CHEMICAL REACTIONS IN THERMIONIC EMISSION. Akad. Nauk. SSSR Dok. 131:357-392, 1960.

In Russian. Abs. in Chem. Abs. 55:15125, 1961.

3181
Pikus, G.E. THE EFFECT OF A MAGNETIC FIELD ON THE OPERATION OF A PLASMA

Calculations show that although the action of the magnetic field produced by the current in plasma thermocouples is significantly less than in a vacumm, it also imposes substantial limitations on the possible electrode dimensions.

3182
Republic Aviation Corp. Plasma Propulsion Laboratory, Farmingdale, N.Y. RESEARCH ON THE EFFECTS OF MAGNETIC FIELDS ON THERMIONIC POWER GENERATION, September 1, 1960 - August 31, 1961. 14p., Oct. 2, 1961. (Prog. Rept. 1) (Contract Nonr-3285(00)) (AD-264 135).

This is the first report of an experimental and theoretical study of magneto-thermionic power generation. Specifically the task is to verify the predicted magnetic field effects, and to examine their possible use in AC generation.

3183
Schock, Alfred. MAGNETO-THERMIONIC POWER GENERATION. Appl. and Indus. no. 58, p. 398-403, Jan. 1962.

A design concept is presented which, under certain conditions, improves the efficiency of thermionic generators. The proposed concept envisages the application of a magnetic field perpendicular to the electrode surface. This applied field counteracts the adverse effect of the self-induced transverse magnetic fields present in large thermionic generators. In addition, the applied magnetic field may be used as a modulating device in order to generate an alternating current. (Article with same title appears in Elec. Eng. 79:973-978, Dec., 1960).

3184
Schock, Alfred and Eisen, C. L. THERMIONIC CURRENT TRANSMISSION IN A STRONG MAGNETIC FIELD. J. Appl. Phys., 33:1-2, Jan. 1962.

In an earlier analysis of the effect of magnetic fields on thermionic diodes, numerical results indicated that under certain conditions the fraction of emitted electrons reaching the collector equals the sine of the angle at which the magnetic field intersects the emitting surface. An analytic proof of this relation has since been found and is presented here.

1. Emission Phenomena

3185
Bussard, R. W. SOME CONSIDERATIONS OF DYNAMIC BEHAVIOR IN THE PLASMA THERMOCOUPLE. J. Appl. Phys., 33: 606-613, figs., Feb. 1962.

An analysis is presented of the role which stable electron oscillations of large amplitude may play in determing observed "steady-state" characteristics of a plasma-filled thermionic diode. The mechanism considered is that of coupling between electrostatic plasma oscillations, driven by the energy of the entrant electron "beam" from the emitter surface, and the potential distribution in the emitter sheath region. In operation such that net current flow is controlled by the sheath potential distribution, it is found that the time-averaged net current may increase markedly in transition from nonoscillatory to oscillatory operation, with a concurrent change in cell and load potential drops such that the diode acts as a negative resistance source of potential over a limited range. Conditions which restrict attainment of the oscillatory mode are discussed, and it is found that large amplitude electron waves may be generated and maintained over a fairly wide, and experimentally accessible range of plasma electron density. Comparison is made with some experimental results, and an experiment is suggested for direct test of the driven-wave hypothesis discussed herein.

3186
D'Angelo, N. LOW-FREQUENCY OSCILLATIONS IN CESIUM THERMIONIC CONVERTERS. Phys. Fluids, 4:1054-1055, Aug. 1961.

Oscillations with frequencies in the 100 kc range were observed in the operation of cesium converters for cathodes at 1350 to 1450°K. The frequencies correspond roughly to those of ion-plasma oscillations and a positive ion sheath may be present near the cathode. (Nuclear Sci. Abs. 15: 26756, 1961).

3187
Dykman, I. M. and Tomchuk, P. M. THE EFFECT OF AN ELECTRIC FIELD ON THE ELECTRON TEMPERATURE, THE ELECTRICAL CONDUCTIVITY AND THERMIONIC EMISSION OF SEMICONDUCTORS. IV. LOW LATTICE TEMPERATURES. Fiz. Tverdogo Tela 3:1909-1919, Jly. 1961.

In Russian. Transl. in Soviet Phys. Solid State 3:1393-1399, Jan. 1962.

The method developed in a previous paper

by the authors (Fiz. Tverdogo Tela 2:2228, 1960) is extended to apply to the case of low lattice temperatures. It is demonstrated that in the impurity scattering region the interelectron interactions have a substantial effect not only on the symmetrical portion of the distribution function but also on its asymmetrical portion. More general formulas are derived for determining the electron temperature and conductivity current; these formulas take into account the indicated variation of the asymmetrical portion of the distribution function. (Phys. Express 4:32:1961).

3188
Herring, C. and Nichols, M. H. THERMIONIC EMISSION. Rev. Mod. Phys. 21:187-270, Apr. 1949.

Provides a detailed and fully documented review of advances in the theory of thermionic emission since 1936. Twenty books are cited.

3189
Hora, Heinrich and Mueller, Henning. PHENOMENOLOGICAL CONSIDERATION ON THE PHOTON-ELECTRON INTERACTION IN A PLASMA. Z. Physik., 164: 359-366, 1961.

The possibility of a simple physical connection between the Richardson equation for thermionic emission and the Richardson equation for photoelectric emission was studied. The proposition of such a connection is based on the following supposition that electrons are not only elements of a (Fermi-Dirac) statistical ensemble and, as such, cause the thermionic phenomena; but that they can also interact with a radiation field, thereby causing an additional emission current, according to the Richardson (photoelectric) equation. (Nuclear Sci. Abs. 16:4924, Feb. 28, 1962).

3190
Kaganov, M. I., Kucherov, R. Ia., and Rikenglaz, L. E. KINETIC THEORY OF A LOW-PRESSURE PLASMA THERMOELEMENT. Zhurn. Tekh. Fiz. 31:588-596, May 1961.

In Russian. Transl. in Soviet Phys. Tech. Phys. 6:420-426, Nov., 1961.

The kinetic theory of a plasma thermal converter is considered under the assumption that the mean free paths for electrons and ions are much greater than the dimensions of the device and that the potential variation in the space between the anode and cathode is monotonic.

3191
Langmuir, D. B. and Hershberger, W. D. FOUNDATIONS OF FUTURE ELECTRONICS. 514p., figs., New York, McGraw-Hill, 1961.

The section devoted to plasma physics, p. 155-324 includes papers by F. E. Jaumot, Jr. and R. W. Pidd. For analysis of contents see separate entries under these authors.

3192
Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass. THERMIONIC EMISSION, by W. B. Nottingham. 1956. (Tech. Rept. 321) (Contract DA36-039-sc-64637) (AD-126 182).

This report makes a study of the more fundamental aspects of the experimental and the theoretical investigations of the phenomenon of electron emission from heated conductors. The study describes the following four surface classifications of transmission emitters and critically reviews important investigations yielding relevant information about them: (1) clean homogeneous surface, (2) clean heterogeneous surfaces, (3) simple composite surfaces, and (4) complex surfaces. A detailed analysis of the present state of our understanding with respect to both theory and experiment is included.

3193
Myatt, J. and Sanders, L. G. A NOTE ON THE THEORETICAL EFFICIENCY FOR ENERGY TRANSFORMATION USING THERMIONIC EMISSION. J. Electron. & Contr., 2:95-99, figs., Aug., 1961.

A theoretical analysis is presented in which it is shown that, when diodes are used as energy transducers, a low cathode work function (e.g. equal to the anode work function) is not compatible with low efficiency.

3194
Ostroukhov, A. A. THEORY OF NON-STATIONERY THERMIONIC EMISSION OF A SEMICONDUCTING CATHODE. Fiz.

Tverdogo Tela 3:3-14, Jan. 1961.

In Russian. Transl. in Soviet Phys. -Solid State 3:1-8; Jly. 1961.

Earlier equations for the rise in thermionic emission of semiconducting cathodes with time are reconsidered with special reference to conditions at the beginning and end of a long anode voltage pulse. The influence of anode voltage and semiconducting parameters on the time dependence of the thermionic current are discussed. Desorption and adsorption of atoms at the cathode surface are related to the magnitude of the current impulse.

C. Electrode Properties

3195
Agishev, E.I. and Belyakov, Yu.I. TRANSIENT THERMIONIC EMISSION FROM NICKEL AND TUNGSTEN IN VACUUM. Zhurn. Tekh. Fiz. 30:223-225, 1960.

In Russian. Transl. in Soviet Phys. Tech. Phys. 5:201-203, 1960.

The experiments described in the present report have been carried out with magnetic pulsed mass spectrometer provided with a special ion source designed for investigations of surface ionization. It is found that with rapid heating ("flash") in vacuum to temperatures of 600-900°C of a nickel emitter which had first been heated and then cooled and which had not been subject to any preliminary processing, the mass spectrum for positive ions exhibits an ion peak at m/e ~ 100 which vanishes after several seconds. With further heating of the emitter one then observes the usual "stationary" peaks of ions of the alkali metals which are typical for these conditions. If the emitter is cooled again the effect can be reproduced.

3196
Agishev, E.I. and Belyakov, Yu.I. THERMIONIC-EMISSION FROM NICKEL [AND PLATINUM] IN THE PRESENCE OF HALOGENS. Zhurn. Tekh. Fiz., 29: 1480-1483, Dec. 1959.

In Russian. Transl. in Soviet Phys. Tech. Phys. 4:1366-1369, 1960.

The authors have carried out mass spectrometer investigations of the emission of positive ions from the surface of an incandescent nickel surface in the presence of CCl_4 vapors and freon. The experiments were carried out in a pulsed mass spectrometer (no magnet). The principles of operation and the general arrangement of the mass spectrometer have been described earlier. Here is considered only the scheme which was developed in connection with investigations of the surface ionization of a pulsed-ion source.

3197
Allied Research Associates, Inc., Boston, Mass.
STUDY OF MATERIALS FOR THERMIONIC CONVERTERS, by P. Goodman and H. Homonoff. 80p., Dec. 31, 1961. (Summary Rept. 1) (Contract Nonr-3385(00)).

Of those properties required for satisfactory, long-lived performance of a material as either the emitter or collector, it was considered that the work function was most critical. Factors, relating to both the crystalline structure and the electronic nature of interatomic interactions, are discussed for the following classes of materials: Metals, ionic solids, metalloids, and semiconductors.

3198
Armour Research Foundation, Chicago, Ill.
SEAL AND INSULATOR PROBLEMS IN THERMIONIC CONVERTERS, February 15, 1961 - February 15, 1962. 82p., illus. Mar. 12, 1962. (Summary Rept.) (Rept. 2215-6) (Contract Nonr-3441(00)) (AD-273 481).

A discussion of the materials requirements for seals and insulators for thermionic enery converters is presented. Based on the requirements and published physical property data, Al_2O_3 appeared to be the most desirable insulator material at temperatures below its melting point. The study includes a discussion of metal ceramic sealing technology and a bibliography of publications in the field covering 1959, 1960, and part of 1961.

3199
Behmenburg, W. THERMIONIC AND INDUCED PHOTOELECTRON EMISSION IN ZINC SULFIDE. Z. Physik. 164:222-228, 1961.

In German. Thermionic emission (TE), thermoluminescence (TL), and induced photoelectron emission (IPE) of ZnS were

investigated after electron bombardment. Unlike other substances, TE and TL in ZnS have different origins; TL is caused by traps within the forbidden energy gap in the interior of the crystal, while a sorption layer on the crystal surface is responsible for TE. IPE is caused by a third mechanism. (Sci. Abs. 64A(Pt. II):18917, Dec. 1961).

3200
Fox, Raymond and Gust, William. THERMIONIC EMISSION CHARACTERISTICS OF A THORIUM CARBIDE HEAT CONVERTER. Am. Phys. Soc. Bull., 5:322, 1959.

Abstract, only, of a paper presented at the Milwaukee meeting of the American Physical Society. It concerns measurement of thermionic characteristics of thorium carbide in a cesium space charge neutralized diode geometry. A guard ring cylindrical diode was built using thorium carbide as the cathode and nickel as the anode. Power input of the diode heat converter was measured from the total power used in heating the cathode. This was checked with the power expended in heating the anode plus the power output of the tube. The two measurements were in agreement. A converter efficiency greater than 15% and an electrical power output greater than 15 w/cm^2 was obtained.

3201
General Atomic, San Diego, Calif. RESEARCH ON CESIUM-VAPOR CELLS EMPLOYING CARBIDE CATHODES, February 1, 1961 - January 31, 1962. 44p., Feb. 1962. (Yearly Tech. Summary Rept.) (GA-2900) (Contract Nonr-3193(00)) (AD-272 752).

Vacuum emission measurements were made on a series of samples consisting of polycarbides of uranium and zirconium. Certain of these carbide samples were incorporated into cesium cells and studies were made of the electrical output characteristics. Results indicated that the cells operate in a discharge mode for cesium pressure exceeding 0.1 mm Hg and that maximum power output has a linear dependence on interelectrode spacing. Observations were made of the effect of cesium adsorption on carbide and refractory metal emitter materials.

3202
Hopkins, B. J. and Vick, F. A. THERMIONIC AND RELATED PROPERTIES OF CALCIUM OXIDE. Brit. J. Appl. Phys., 9: 257-264, 1958.

Using probe diodes, changes in thermionic emission and conductivity of cathodes of calcium oxide on nickel were followed during activation and poisoning. The effects of material liberated from the anode were studied. The mean nominal thermionic work function is 1.69 ev for the fully activated cathode with an estimated temperature coefficient of 1.1 mV/deg K for the two at the lowest temperatures are 1.3 and 0.81 ev. The current-voltage characteristics between the cathode base and probe show two types of curvature, one dominant above 625 K and the other below this temperature. A linear relation extending over four orders of magnitude between the logarithms of emission and of the conductivity was observed during activation. Assuming that semiconductor theory may be applied, the mean value of the surface work function is calculated to be 0.7 ev. (Semiconductor Abs. 6:22, 1958).

3203
Hutson, A. R. VELOCITY ANALYSIS OF THERMIONIC EMISSION FROM SINGLE-CRYSTAL TUNGSTEN. Phys. Rev. 98: 889, May 15, 1955.

A 180-deg magnetic velocity analyzer tube has been used to observe the energy distributions of the thermionic emission from various crystallographic directions of a single-crystal tungsten filament. The distributions were the same in all of the directions and were not Maxwellian. An energy-dependent reflection coefficient for the tungsten surface, previously proposed by Nottingham, is capable of explaining the shape of the distributions. The tube permitted measurements of the differences between the true work functions of the various directions. The changes of true work functions with temperatures between 1700 -2000°K were also measured for all directions except the (110). The non-Maxwellian character of the energy distributions and the temperature variations of the work functions can largely explain the discrepancy between the emission constant, A = 120 of Richardson's equation and the Richardson-plot emission constants obtained for the various directions of a tungsten crystal by Nichols and by Smith. Also issued as MIT Tech. Rept. 260.

3204
Ingold, J. H. THERMIONIC PROPERTIES OF HfC. J. Appl. Phys. 32:2651, Dec. 1961.

The thermionic emission properties of bulk HfC have been measured over the temperature range 1300 to 2100°K.

3205
Massachusetts Institute of Technology. Research Laboratory for Electronics, Cambridge, Mass.
THERMIONIC EMISSION FROM OXIDE-COATED TUNGSTEN FILAMENTS, by C. P. Hadley. 25p., diags., Dec. 11, 1961. (Tech. Rept. 218) (Contract DA36 039-sc-100).

A study of the filaments cataphoretically coated with alkaline earth oxides revealed that emission from the oxide-coated filament was not influenced by the variation of work function with crystallographic direction of the base metal. The apparent deviation of thermionic electrons from Maxwell-Boltzmann statistics was interpreted as due to a potential drop through the coating. This interpretation led to a method for studying the resistive properties of the coating. (Also in J. Appl. Phys. 24:49-52, Jan. 1953.)

3206
Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass.
VELOCITY ANALYSIS OF THERMIONIC EMISSION FROM SINGLE-CRYSTAL TUNGSTEN, by A. R. Hutson. 13p., illus., Jan. 13, 1955. (Tech. Rept. 260) (Contract DA36-039-sc-42607).

A 180° magnetic velocity analyzer tube has been used to observe the energy distributions of the thermionic emission from various crystallographic directions of a single-crystal tungsten filament. The distributions were the same in all of the directions and were not Maxwellian. An energy-dependent reflection coefficient for the tungsten surface, previously proposed by Nottingham, is capable of explaining the shape of the distributions quite well. The tube permitted measurements of the differences between the true work functions of the various directions. The changes of true work-functions with temperature between 1700° and 2000°K were also measured for all directions except the (110). The non Maxwellian character of the energy distributions and the temperature variations of the work functions can largely explain the discrepancy between the emission constant, A = 120, of Richardson's equation and the Richardson plot emission constants obtained for the various directions of a tungsten crystal by Nichols and by Smith. (Also in Phys. Rev. 98:889-901, May 15, 1955).

3207
Morgulis, N. D. and Korchevoi, Yu. P. THERMIONIC CONVERSION OF THERMAL ENERGY TO ELECTRICAL ENERGY BY THE USE OF THORIUM CARBIDE. Atomnaya Energ. 9:49-51, 1960.

In Russian. Transl. AEC-tr-4621 available from JCL or LC.

3208
Naval Research Laboratory, Washington, D.C. THERMIONIC ELECTRON SOURCES, by G. A. Haas. 28p., figs., Oct. 6, 1961. (Rept. 5657).

A survey of the emission characteristics of modern thermionic electron sources is presented. In addition to a discussion of recent advances among the more commonly used emitters such as oxide cathodes, thoriated cathodes, and metal cathodes, a tabulation of the thermionic properties of over one hundred various new matrix and refractory coated cathodes is given.

Information in this report is substantially the same as that contained in ch. 7.7, vl. 6B, of Methods of Experimental Physics.

3209
Samsonov, H. V., Neshpor, V. S., and Paderno, Yu. B. THERMIONIC [ELECTRON] EMISSION PROPERTIES OF METAL-LIKE COMPOUNDS. Ukrain. Fiz. Zhurn., 4:508-518, 1959.

In Ukrainian. An explanation is given of the electric properties the work function of the transition elements and their compounds with boron, carbon, silicon, and nitrogen. Methods are described for obtaining hexaborides of rare-earth metals, their pseudobinary alloys and sintered samples of these materials. (Sci. Abs. 64A:13103, 1961).

3210
Smorodinova, M. I. and Sytaia, E. P. STUDY OF THE CHANGES IN THERMIONIC PROPERTIES OF RHENIUM COATED

TUNGSTEN CATHODE. Sredneaz. Gosudarst. Univ. Trudy. Tashkent. no. 148: 9-22, 1959.

In Russian. For abstract see Chem. Abs. 55:6142, Apr. 3, 1961.

3211
Stephas, Paul. SEARCH FOR A NUCLEAR THERMIONIC EMITTER. Nucleonics 19:66, 70, 72-73, Dec. 1961.

Requirements for a suitable material are indicated; several materials are mentioned; and a table (p. 72) lists thermionic properties of promising materials.

3212
Thermo Electron Engineering Corp, Waltham, Mass.
THERMIONIC EMITTER MATERIALS RESEARCH PROGRAM, July 1- September 30, 1961. 115p., Sept. 1961. (Quart. Rept. 1) (TEE-4015-1) (Contract Nonr-3563(00)) (AD-267 010).

Studies were made of refractory metals as emitter materials for thermionic converters. Two diodes were tested. One used a tantalum emitter and a molybdenum collector, the other used molybdenum for both. Current-voltage (I-V) characteristics were determined. Under certain conditions the I-V curves exhibited two branches. Each branch approached a constant current value as output voltage was reduced. This behavior led to the association of an apparent work function with each constant current value. A technique was developed for measuring the ion current in the experimental diode. Methods were also developed to determine electron cooling and heat conduction by cesium vapor.

3213
U.S. Atomic Energy Commission, Argonne National Laboratory, Lemont, Ill.
THERMIONIC ENERGY CONVERSION DIODE USING A FILM BOILING LIQUID METAL ANODE, by A. J. Ulrich. 11p., Dec. 1961. (Rept. 6465) (Contract W-31-109-eng-38).

The conventional plasma thermocouple or thermionic energy conversion diode has a solid metal anode. Cs vapor at a pressure of a few millibars or less is widely used to provide ions for electron space charge neutralization. Usually, conditions are such that a monolayer of Cs coats the anode, so that electrically the anode appears to be Cs. This suggests the use of a diode with a liquid metal anode material such as Cs, Rb, or K, and their alloys. Recent experiments showed that a diode, consisting of a hot cathode and a liquid metal anode separated by the vapor film created in film boiling, can be produced. Data are given. Experiments investigating the electrical characteristics of film boiling using water are described.

3214
Yang, Ling and Carpenter, F. D. MATERIALS PROBLEMS IN CESIUM THERMIONIC CONVERTERS. Electrochem. Soc. J. 108: 1079-1086, illus., Nov. 1961.

The unique features associated with a cesium thermionic converter which are the causes of serious materials problems, are (a) high temperature, (b) partial vacuum, (c) presence of cesium vapor, (d) close spacing between the electrodes, and (e) presence of intense radiation and fission products (only for the conversion of fission heat). Special consideration must be given to the materials problems, and the proper selection of these materials must be made if the device is to deliver useful and dependable performance for long periods of time (e.g., several watts per square centimeter or more output, 25% or better efficiency of conversion, one year or longer life). The materials problems are analyzed in detail.

3215
Zubenko, Yu. V. and Sokol'skaya, I. L. FIELD EMISSION AND THERMIONIC EMISSION OF THORIUM AND BARIUM LAYERS ON TUNGSTEN. Fiz. Tverdogo Tela 3: 1561-1565, May 1961.

In Russian. Transl. in Soviet Phys. Solid State 3:1133-1136, figs, Nov. 1961.

A study was made of thermionic and field emission of tungsten as a function of thickness of a thorium and barium layer deposited onto it. It is shown that upon depositing thorium or barium on tungsten, emission increases monotonically; no maximum is discovered which is ascribed to the usual monotomic coating. The conclusion is reached that a monatomic change in emission with coating is characteristics for absorbed layers of metal on metal, and the emergence of a maximum is connected with chemisorbed oxygen on tungsten.

D. Plasma Properties

3216
Aerospace Corp., El Segundo, Calif.
ENERGY CONVERSION INCLUDING MAGNETOAERODYNAMIC STUDIES AND THERMIONIC CONVERTERS. THERMIONIC CONVERTER STUDIES, by R.C. Horn. 23p., illus., June 30, 1961. (Semiannual Tech. Rept.) (Rept. TDR-594(1201-03) (TR-1, Pt. 2) (Contract AF04(647)594) (AD 266 440).

A plane parallel cesium thermionic converter was constructed, and is about to be put into operation. A second converter, which permits spectrographic determination of cesium species temperatures and densities, was designed. Analytical studies of plasma and sheath phenomena occurring in high pressure operation of a converter are in progress.

3217
Bernstein, W. and Knechtli, R.C. A NEW APPROACH TO THERMIONIC ENERGY CONVERSION: SPACE CHARGE NEUTRALIZATION BY AN AUXILIARY DISCHARGE. Inst. Radio Engrs. Proc. 49: 1932-1936, figs., Dec., 1961.

The characteristics of an auxiliary discharge thermionic energy converter are derived and compared with experimental results. It is shown that the power expended in the auxiliary discharge can be as low as 10 per cent of the power generated by the converter. Thus, efficiencies of about 25 per cent and power output densities as high as 10 w/cm^2 can be obtained at temperatures of about 1500°K provided that low work function anodes are developed. The specific advantages of the auxiliary discharge technique over the conventional cesium converters are discussed.

3218
General Atomic, San Diego, Calif.
DIRECT CONVERSION -- THERMAL TO RADIOFREQUENCY ENERGY, Final Report, by J.F. Colwell and Hugh Garvin. 44p., illus., Oct. 31, 1961. (Rept. GA-2535) (RADC TR-61-244) (Contract AF30(602)-2437) (AD-266 283).

An analytical and experimental program was carried out to determine the parameters for utilizing the cesium-vapor diode as a direct converter of thermal energy to electromagnetic energy in the radio-frequency (rf) range above 50 Mc/sec. The theoretical study concerned the plasma conditions which exist in a cesium diode with parallel-plane geometry, and predictions were made of the nature of the oscillatory plasma modes which might couple to a radiation field. The experimental program sought to determine if rf signals (above 50 Mc/sec) could be observed to emanate from a cesium-vapor diode. Signals were observed in the kilomegacycle frequency range which were found to depend critically on conditions of plasma temperature and density. The energy content is judged to be of the order of KT: the frequency was within 30% of the calculated plasma frequency.

3219
General Motors Research Laboratories, Warren, Mich.
INVESTIGATIONS ON THE DIRECT CONVERSION OF NUCLEAR FISSION ENERGY TO ELECTRICAL ENERGY IN A PLASMA DIODE, by F.E. Jamerson. 1v., illus., Jan. 31, 1962. (Annual Rept.) (Contract Nonr-3109(00)) (AD-273 067).

Results of experimental and theoretical investigations are presented on the use of a nuclear generated plasma in a noble gas plasma diode thermionic converter. Related programs of emitter materials development and plasma measurements are described. These are presented in the following individual reports: Noble Gas Plasma Diode Inpile Experiment IV; Noble Gas Plasma Diode Inpile Experiment V; A Plasma Sheath Theory with Voltage-Independent Ion Source; The Development of Emitter Materials for Use in the Noble Gas Plasma Diode; Thermionic Emission of UC-Nb and UC-Re; and Spectroscopic Measurements of Plasma Temperatures and Densities in a High Pressure Cesium Diode.

3220
Hughes Research Laboratories, Malibu, Calif.
CESIUM PLASMA STUDIES FOR THERMIONIC ENERGY CONVERSION, by R.C. Knechtli and J.Y. Wada. 3 issues. Oct. 1961, Apr., June 1962. (Semiannual Tech. Summary Repts. and Final Rept.) (Contract Nonr-3501(00)).

A new method for measuring the volume recombination coefficient α of thermal cesium plasmas in steady state has been devised and perfected. In this method, a

thermal cesium plasma column is magnetically confined between two plasma generators. The plasma is generated by contact ionization and thermionic emission. The rate of plasma generation is controlled by the cesium vapor pressure in the device, the latter being directly measured in absolute value. The rate of plasma loss (in the range of measurement of α) is predominantly controlled by volume recombination, i.e., by α and by the plasma density. The latter is measured by Langmuir probes. The recombination coefficient is then found as a function of the measured ion and neutral densities by equating the rates of ion generation and ion loss.

3221
Morgulis, N. D. and Korchevoi, Yu. P. SOME PROBERTIES OF THE CESIUM PLASMA THERMOELECTRON ENERGY CONVERTER. Akad. Nauk. SSSR. Dok. 136:336-338, 1961.

In Russian. NRL Transl. 846, by A. Pingell, available from OTS, 61-31542. Eng. Transl. also in Soviet Phys. -Dok. 6: 71-73, Jly. 1961.

A short report on the characteristics of a discharge in vapor between thorium carbide and tantalum electrodes investigated by a probe method. Tables and graphs relating the behavior of typical quantities are given, together with a qualitative discussion of the results.

3222
Morgulis, N. D., Korchevoi, Iu. P., and Chutov, Iu. I. SOME PHYSICAL CHARACTERISTICS OF THE THERMIONIC CONVERSION OF ENERGY. Zhurn. Tekh. Fiz. 31:845-853, Jly. 1961.

In Russian. Transl. in Soviet Phys. Tech. Phys. 6:611-616, Jan., 1962.

The question of converter emf was examined and experiments were conducted to determine how it depends on the temperature of the cathode and the pressure of the Cs vapor. Because of a limited understanding of this emf, the introduction of the maximum (power) output potential difference of the converter is proposed as an auxiliary, more useful parameter. The dependence of the latter on the temperature of the cathode was measured for six different types of cathodes.

The properties of the tungsten cesium system have been examined in connection with energy conversion at relatively low temperatures for: (a) low temperature cathodes at optimum emission, corresponding to a single atom layer and small work function, and (b) higher temperatures with an almost glowing base. The experimental properties of this system were determined for Cs vapor at different pressures; it was found that the Cs thermions play a very important role as a supplementary source.

3223
Ruth, J. P. CESIUM MAY DRIVE ENGINES AND ENERGY CONVERTERS. Am. Metal Market 68:14, Aug. 1, 1961.

Applications of Cs in ionic engines and thermionic converters. Possible use as fuel in space vehicles after gravity has been overcome. Manufacturers in U. S. A. Cost is $375 per lb (1-4lb) or $1 per gram. (Brit. Non-Ferrous Met. Res. Assoc. Bull. Note 2961, Nov., 1961).

3224
Schuder, J. C. COMMENTS CONCERNING THE POSSIBLE USE OF GAS PLASMA IN THERMOELECTRON ENGINES. Inst. Radio Engrs. Proc. 47:104, Jan., 1959.

The thermoelectron engine, in contrast to the one developed by Hatsopoulos and Kaye, employs large spacing of electrodes by using a gas plasma with substantially equal electron and positive ion space charge density in the interelectrode space.

E. Design Parameters

3225
Baum, E. A. and Jensen, A. O. THERMIONIC CONVERTERS - DESIGN STATUS AND FORECAST. In Power Sources Conference. Proceedings, 15th, 1961, p. 143-148, Red Bank, N. J., PSC Publications Committee, 1961.

The discussion is limited, primarily, to data and prospects for arc-mode vapor thermionic converters operating with cathode temperatures of about 1500°C and below.

3226
Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

DESIGN CONSIDERATIONS FOR A PLASMA THERMOCOUPLE REACTOR, by B. E. Watt. 24p., May 13, 1960. (Rept. LAMS-2386) (Contract W7405-eng-36).

General features of a nuclear reactor-plasma thermocouple power system are investigated. Only simple plasma cells are considered, for which all the experimental data and most of the theory were presented elsewhere. From the available information it is concluded that the reactor should be a heterogeneous system alternating hot junctions (reactor fuel) and cold junctions (liquid metal coolant preferred) and must contain a large number of cells. Uncertainties in many of the important parameters and in the design concepts leave the conclusions open to debate and emphasize the need for more experimental and theoretical work.

3227
Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
LASL PLASMA THERMOCOUPLE DEVELOPMENT PROGRAM, by Samuel Glasstone. 16p., Oct. 1959. (Quart. Status Rept. for Period Ending Sept. 20, 1959). (Rept. LAMS-2364).

A "standardized" basic design of a plasma thermocouple for in-pile testing was selected. A pyrometer, thermal conductivity, and life tests were accomplished.

F. Devices

3228
Bloss, W. UEBER EINE ANORDNUNG ZUR DIREKTUMWANDLUNG VON WAERME-ENERGIE IN ELEKTRISCHE ENERGIE. (ON AN ARRANGEMENT FOR THE DIRECT CONVERSION OF HEAT ENERGY INTO ELECTRICAL ENERGY). Naturw. 48:497, Jly. 1961.

In German. Describes a plasma diode which has a BaO heated cathode and a semiconducting layer on the anode. The positive ions for space-charge compensation are provided by an argon or krypton discharge between the main cathode and a small auxiliary heated cathode. The output current depends on the current and burning voltage of this auxiliary discharge. Efficiencies of 8.6% have been obtained and occasionally up to 20%. The advantages claimed are the low working temperature of the cathode and the possibility of obtaining an alternating output by switching the auxiliary discharge. (Sci. Abs. 64A(Pt. II); 18748, Dec. 1961).

3229
Hall, W. B. and Hernquisy, K. G. THE PLASMA TRIODE - A LOW TEMPERATURE THERMIONIC CONVERTER. In Power Sources Conference. Proceedings, 15th, 1961, p. 148-150, Red Bank, N. J., PSC Publications Committee, 1961.

Requirements, experimental studies of plasma synthesis, and development of devices are discussed.

3230
McAllister, J. F. STATUS OF THERMIONIC CONVERTERS. Signal 16:50-51, Nov. 1961.

Two types are described (the vacuum, and the vapor) and their applications indicated (for solar probes and orbits; for low probes; as light-weight, portable generators; in universal protective clothing system being developed by the Army Quartermaster Corps). Two special projects are briefly mentioned - STEPS and STAR.

3231
Miller, Barry. THERMIONIC CONVERTER READIED FOR SPACE. Aviat. Wk. and Space Tech. 76:109, 111, 113, Apr. 16, 1962.

Componets are described of a system called SET(Solar Energy Thermionic Conversion system). Its design falls within an envelope of parameters suitable for an Atlas-Centaur boosted Mariner spacecraft.

3232
PLASMA THERMOCOUPLE CONVERTS ENERGY DIRECTLY. Elec. Eng. 78:878, Aug. 1959.

A brief article quotes R. W. Pidd, who was connected with "the first known direct conversion of nuclear energy into electric power". Under the process, electric power is obtained from a nuclear reactor containing a uranium carbide source surrounded by a plasma or electrified gas made from cesium.

3233
SUMMARY OF MEASUREMENTS OF THERMOELECTRIC CONVERSION WITH VARIOUS CESIUM FILLED THERMO-ELECTRONIC DIODES. 14p., 1960. (Transl. DTW-2276).

Transl. of unidentified French monograph. Order from LC or SLA.

Results are given of a preliminary experimental study of the influence of the properties of the emitter and collector materials, the emitter-collector distance, and the vapor pressure of cesium on the efficiency and electric power conversion. The emitter was heated by Joule's effect. (Tech. Transl. 5:245, Mar. 14, 1961).

3234
Ushakov, B. A. THERMIONIC ENERGY CONVERTERS. Atomnaya En. 10:343-346, Apr. 1961.

In Russian. Direct conversion of nuclear energy into electric energy, based on thermionic devices, is investigated. Various materials possessing good thermo-emission properties are analyzed, and results of tests with a converter in an active reactor zone are reported. The experiments demonstrate that during operation an inert gas filled converter becomes a cesium plasma diode, eliminating the use of cesium vapors and improving the performance and life of the converter. (Nuclear Sci. Abs. 15:28167, 1961).

G. Systems

3235
BIG GE SOLAR POWER SYSTEM TESTED. Missiles and Rockets 9:37, illus., Dec. 18, 1961.

A brief description is given of "the largest solar thermionic power system reported in the U.S." which is now functioning in a new solar test facility near Phoenix, Ariz.

3236
General Atomic, San Diego, Calif. THERMIONIC POWER APPLICATION FOR SPACE SYSTEMS, by R. W. Pidd. 5p., 1961. (Status Rept.) Paper 2123-61 for presentation at American Rocket Society, Space Flight Report to the Nation/New York Coliseum, October 9-15, 1961.

The application and status of thermionic power conversion for space power was illustrated in terms of a system using a reactor heat source. Systems studies indicate a useful power output of 100 to 10000 kw(e). An application of the converter for lower power capacities uses solar heating with a solar collector to produce the high operating temperatures. (Nuclear Sci. Abs. 15:31912, 1961).

3237
General Electric Co., Philadelphia, Pa. SOLAR THERMIONIC ELECTRICAL POWER SYSTEM, by D. L. Kerr and D. J. Cuthbert. 78p., illus., Jly. 1961. (Semiannual Rept. 2) (WADD TN 61-56) (Contract AF33(616)7008) (AD-260 983).

Efforts are being made to design and develop a Solar Thermionic Electrical Power System (STEPS). A schematic of the STEP system is presented. A parabolic solar collector, approximately 16 ft in diameter, transmits thermal energy to the generator. The generator consists of a biconic, cavity-type absorber with a circular aperture about 5 inches in diameter through which the thermal energy is focused. Mounted on the external rear surface of the absorber are 105 vacuum thermionic converters. These converters are connected to form 2 separate electrical circuits: (1) the load generator, consisting of 48 converters electrically connected in series, and (2) the battery charging generator, with 57 converters also in series. STEPS is designed to operate continuously throughout a 52 minute light, 38 minute dark cycle. During operation in sunlight, the load generator supplies the load through a shunt regulator, while the battery charging generator charges the battery, which is disconnected from any load. During operation in the dark, the battery supplies the load through a series of regulator, and the battery charging generator is disconnected from the load.

3238
THERMIONIC CONVERTER FOR SPACE LABORATORIES. Eng. 193:189, Feb. 2, 1962.

An annoucement is made relative to a direct conversion system in the 60 and 300 kw power range and a 2,000 kw reactor under conceptual development.

3239
THERMIONIC REACTOR HELD FEASIBLE AS EARLY AS 1966. Elec. Eng. 80:986, Dec. 1961.

A brief article mentions and includes an illustration of an atomic reactor using thermionic units in its fuel elements to convert heat directly into electricity.

3240
Thompson Ramo Wooldridge, Inc., Cleveland, Ohio.
DESIGN STUDY FOR ADVANCED SOLAR THERMIONIC POWER SYSTEMS. Item II, parts I and II, Item III. 3 issues, Sept., Dec. 1960. (Eng. Repts. 4166, 4262) (WADD TR 60-698, pt. 1 and 2; WADD TR-60-872) (Contract AF 33(616)7411) (AD-267 330; 260 066 and 260 068).

Results of a theoretical and experimental study of electrical characteristics of cesium-vapor and vacuum thermionic generators are presented.

IV. PHOTOELECTRIC PROCESSES

A. Photovoltaic

1. Theory

3241
Shockley Transistor Unit. Clevite Transistor Research and Development Laboratory, Mountain View, Calif.
RESEARCH STUDY OF PHOTOVOLTAIC SOLAR CELL PARAMETERS, Final Report, by W. Shockley and H. J. Queisser. 47p., Oct. 1961. (ASD TR 61-423) (Contract AF33(616)-6707) (AD-269 376).

Efficiency limitations for P-N junction solar cells are covered in a theoretical study.

3242
Bardsley, A. SILICON PHOTOCELLS. THE USE OF PHOTOCELLS IN INSTRUMENTATION AND SOLAR POWER APPLICATIONS. Radio & Electron. Comp. 3: 219-224, figs., Mar. 1962.

The theory of operation of a photovoltaic cell is discussed and the effects of this on the spectral response of the cell and the resultant dc and ac equivalent circuits discussed. These components are suitable for a very wide range of applications and the paper ends with an outline of these.

3243
Nadzhakov, G. and Andreichin, R. THE CONTACT-POTENTIAL PHOTOVOLTAIC EFFECT. Izvest. Fiz. s Aneb, Bulgar. Akad. Nauk. 8:5-18, 1960. Not examined. Abs. in Chem. Abs. 55:24266, 1961.

3244
Wayne University. Chemistry Department, Detroit, Mich.
PHOTOVOLTAIC CELLS IN SOLAR ENERGY CONVERSION, by D. Trivish, P. A. Flinn, and H. J. Bowlden. 11p., diags., 1954. (Contract AF18(600) 481).

The function and mechanism of n-p type photovoltaic cells are illustrated and described. Various factors affecting the power efficiency for conversion of solar into electrical energy are briefly analyzed and discussed. Measured values for commercial selenium cells of 1.5 cm^2 area at various qualities and intensities of light are tabulated with regard to short circuit current, open circuit potential maximum power, quantum yield, voltage and power efficiency.

3245
Wayne University. Chemistry Department, Detroit, Mich.
THE MAXIMUM EFFICIENCY OF SOLAR ENERGY CONVERSION BY QUANTUM PROCESSES, by D. Trivich and P. A. Flinn. 8p., 1954. (Contract AF 18(600) 481).

A method is presented for the calculation of the maximum conversion efficiency of photovoltaic cells considered as converting solar energy into electrical by quantum processes. Mathematical expressions are developed for computing the total useful solar radiation absorbed by such a cell above a threshold frequency v_o and for the maximum efficiency for any given value of v_o. The optimum threshold wavelength of solar radiation received at the earth's surface is found to be about 11,600A^o; the efficiency for this choice of threshold is 40% or more. Possible increase in efficiency by use of multiple converters or by minimizing back diffusion is cited, and the calculation of the optimum threshold and efficiency is appended.

2. Silicon Cells

3246
General Electric Co. Advanced Semiconductor Laboratory, Syracuse, N.Y.
UNIQUE PHOTOVOLTAIC CELLS, by J. F. Elliott. 162p., Aug. 1961. (ASD TR 61-242) (Contract AF 33(616)7183) (AD-267 519).

Four major areas have been investigated in an effort to improve one or more of the following figures of merit of photovoltaic

solar energy converters; power output per unit cost, weight, or surface area. Polycrystalline CdTe has been investigated as a solar cell material. The work has not established any fundamental physical reason why this material should not be useful for this purpose. Attempts to construct a composite cell from a Se, CdN, or CdSe cell in optical series with a Si cell have not produced a composite cell with efficiency greater than that of the Si cell alone. The possiblity of using a variable band gap material (i.e., material that has a band gap which is a function of one of the linear dimensions of the material) for a high efficiency converter has been examined theoretically. This analysis indicates that present semiconductor materials have not reached a state of development which would permit a useful cell to be constructed. Different design considerations for a conventional silicon solar cell were studied. Several of these would apparently make second order improvements in the conversion efficiency.

3247
Babcock, R.V. AN EXPLANATION OF THE SUPERIOR RADIATION RESISTANCE OF p-TYPE BASE Si SOLAR CELLS. Electrochem. Soc. J.; 108:1119-1122, Dec. 1961.

Recent studies have shown p-type base Si solar cells to be considerably more resistant to 750 kev electron damage than similar n-type base cells. In this paper, the effects of electron flux on solar efficiency, current voltage characteristics, and spectral response are predicted on the assumption that the only significant damage mechanism is decrease in the minority carrier lifetime in the base region. The calculations agree well with the reported electron damage effects, except that a rapid initial loss in efficiency of about 1% observed in n-type base cells is not reproduced. The usual method of measuring solar cell efficiency, comparing the response to a 2800°K tungsten light with that of a calibrated solar cell, was found to overestimate the effect of electron damage on the actual solar efficiency by as much as 200%.

3248
Barto, C.H. ENERGY CONVERTERS. British Patent 862, 117 (to Union Carbide Corp.), Dec. 31, 1959.

Solar energy cells consisting of n-type Si wafers plated on one side with Al are fitted between Al and Sn terminals. The stacked assembly is preferably heated to 960°C to ensure adhesion to the vacuum-evaporated Al plating which is 0.7μ thick. (Light Met. Bull. 23:1431, Mar. 29, 1961).

3249
Ben-Sira, M.Y. and Pratt, B. SOME FACTORS DETERMINING THE CHARACTERISTICS OF SILICON PHOTOVOLTAIC CELLS. Semiconductor Prod. 5:45-49, Feb. 1962.

Factors determining the characteristics of the solar cell are discussed. The special features of the junction and the photoactive layer of the solar cell are described and related to the resistivity of the starting material and the impurity diffusion cycle. Experimental data of current-voltage characteristics are given for various solar cells and shown to be qualitatively in agreement with the theoretical discussion.

3250
Denney, J.M. and others. ESTIMATE OF SPACE-RADIATION EFFECTS ON SATELLITE SOLAR-CELL POWER SUPPLIES. Inst. Radio Engrs. Trans. MIL-6:14-20, figs., Jan. 1962.

The charged-particle intensity and energy distribution at the heart of the inner and outer Van Allen belts is compared with the experimentally determined radiation sensitivity of silicon solar cells. Energy dependence of the radiation damage and solar-cell characteristics is included in the lifetime estimate of spacecraft solar cells. Use of charged-particle range-energy relations and the differential intensity of the Van Allen radiation results in an estimated effectiveness of thin protective shields. Comparative advantages of thin shields, advanced cell designs, solar efficiency, and solar-cell system over-design are discussed with respect to radiation resistance of spacecraft power supplies.

3251
Electro-Optical Systems, Inc., Pasadena, Calif. RADIATION RESISTNAT SOLAR CELL, by S. Kaye. 2 issues, Dec. 15, 1961, Jan. 15, 1962. (Repts. 2080-ML-1, -2) (Contract NAS7-92).

Work is reported on both the fabrication and theoretical investigation of radiation

resistant solar cells. A number of cells ha have been fabricated using the design described previously. Electro-optical properties of these cells have been measured, but none have, as yet, been submitted for radiation testing. A more exact theory for the transit time across the base region of the cell has been developed.

3252
Elliott, J. F., Halsted, R. E. and Coghill, H. D. LARGE AREA FILM TYPE SOLAR CELLS. In Power Sources Conference, Proceedings, 15th, 1961, p. 109-110, Red Bank, N. J., PSC Publications Committee, 1961.

Programs at General Electric are described. They concern thin film silicon and thin film cadmium telluride cells.

3253
Grace, W. R. & Co., Clarksville, Md. INVESTIGATION OF THIN SHEETS OF HIGH QUALITY SINGLE-CRYSTAL SILICON, by F. T. Fitch. 3 issues, 1960. (Repts. 1, 2, 3(Final)) (Contract DA36-039-sc-85242).

The investigation was conceived preparatory to development of the essential conditions and equipment for continuous crystallization of thin sheet silicon and the evaluation of the material produced to determine its suitability for use in solar cells and other semiconductor devices. Limitations, however, developed of not being able to obtain the silicon sheet as a single crystal. The general conclusion was that lead vapor problems, materials of construction, control of impurities, and unsuitable molten silicon lens characteristics all present difficult working conditions which appear to be subject of sufficient improvement and control to permit the pulling of relatively thin silicon sheets probably in the range of 1.0 to 0.1mm thickness. However, silicon sheets pulled on a molten lead surface would not be obtained as a single crystal due to interference from the crystallization of the small quantities of silicon dissolved in the lead phase.

3254
Great Britain. Royal Aircraft Establishment, Farnborough. THE CALIBRATION OF STANDARD SOLAR CELLS, by F. C. Treble. 17p., Dec. 1960. (Tech. Note EL 190).

An account is given of the calibration of a number of typical solar cells and suggestions are made for further work in this field.

3255
Heaps, J. D., Tufte, O. N., and Nussbaum, A. VAPOR-DEPOSITED POLYCRYSTALLINE SILICON SOLAR CELLS. Inst. Radio Engrs. Trans. ED-8: 560, figs., Nov. 1961.

Because of the high cost of silicon single crystal solar cells, a look was taken into the problem of producing polycrystalline cells with efficiences of 1 per cent or greater. The method investigated is that of depositing from the vapor phase a thin layer of polycrystalline silicon onto a substrate. A p-n junction is formed near the surface of this layer and the resulting photovoltaic properties are measured. The efficiencies were obtained without optimization of many important conditions such as doping levels and electrode configuration. Optimizing these conditions and increasing the silicon crystallite size may increase the efficiency of these cells well above the presently reported values.

3256
Hoffman Electronics Corp., El Monte, Calif. FORMATION OF SILICON SPHERES FOR THE MULTI-ELEMENT LARGE AREA SOLAR CELL, by I. Massaron and H. F. Biekofsky. 3 issues, Aug. 14, 1961, Feb. 14, 1962. (Tech. Summary Repts. and Final) (Repts. 1, 2 and Final) (Contract DA 36-039-sc-87420).

Experimental difficulties are mentioned; and conclusions and comments are presented about production of medium efficiency, inexpensive solar cells.

3257
Honeywell Research Center, Hopkins, Minn. LARGE AREA THIN SOLAR CELLS, by J. D. Heaps and J. Pone. 43p., Dec. 31, 1961. (Semiannual Tech. Summary Rept.) (Rept. 1) (Contract DA 36-039-sc-88981) (AD-272 829).

This represents a study of the possibilities of solar energy conversion using the photovoltaic effect in thin films of polycrystalline silicon.

3258
Iles, P. A. THE PRESENT STATUS OF

SILICON SOLAR CELLS. Inst. Radio Engrs. Trans. MIL-6:5-14, figs., Jan. 1962.

The present state of the art of silicon solar cells is described. The physical properties, circuit performance, and current lines of research are summarized. Silicon is seen to be competitive in several of the newer approaches to solar cell improvement. Includes 42 references.

3259
Lamond, Pierre and Berman, P. RECENT ADVANCES IN N ON P CELLS. In Power Sources Conference. Proceedings, 15th, 1961, p. 106-108, Red Bank, N. J., PSC Publications Committee, 1961.

Methods of fabrication of N on P solar cells is briefly reviewed. Spectral response curves of P on N and N on P solar cells of similar electrical characteristics are compared. Results on electron and proton radiation damage in both types of cells are presented. Possible mechanisms accounting for the different behavior of both types of cells are mentioned.

3260
Lockheed Aircraft Corp., Sunnyvale, Calif. PROTON DAMAGE TO SOLAR CELLS, by K. T. Chow and E. A. Lodi. 31p., illus., Aug., 1961. (Tech. Rept.) (Rept. LMSD-703735-1) (Contract AF 04(647)564) (AD-265 213).

The performance was evaluated of commercially available silicon solar cells which are to be used as power source in the space radiation field surrounding the earth. The experiment was specifically designed to provide information on the proton radiation encountered by solar cells operating in space. The results indicated that a 25% reduction in maximum power output of the cell occurred at integrated fluxes of approximately 5 x 10 to the 9th and 10th power protons/sq cm for 3-Mev and 13-Mev protons, respectively. The cells were further irradiated to obtain a reduction in maximum power output of about 40 to 50%. Room-temperature annealing of the cells was observed for a period of four weeks with no significant changes occurring. The proton source, the apparatus for measuring the electrical output of the solar cell, and the results of the experiment are presented.

3261
Mandelkorn, J. and others. BEHAVIOUR OF MODIFIED RADIATION-RESISTANT SOLAR CELLS. In Power Sources Conference, Proceedings, 15th, 1961, p. 102-105, Red Bank, N. J., PSC Publications Committee 1961.

An investigation is reported to determine the influence of the modifications made to the phosphorous diffused solar cell on the radiation resistance of the cell. It is revealed that high-efficiency cells with improved collection, low "A" values, and low reverse currents can be consistently fabricated by diffusion in the 850°C to 1000°C range. At the lower temperature limit, significant improvement in "blue" collection is obtained at the expense of higher sheet resistance.

3262
Mandelkorn, J. and others. FABRICATION AND CHARACTERISTICS OF PHOSPHORUS DIFFUSED SILICON SOLAR CELLS. Electrochem. Soc. J. 109:313-318, figs., Apr., 1962.

Results of an experimental study of fabrication processes for making phosphorous-diffused silicon solar cells are presented.

3263
Pfeiffer, C. and others. PERFORMANCE OF SILICON SOLAR CELLS AT HIGH LEVELS OF SOLAR RADIATION. Am. Soc. Mech. Engrs. Trans. Ser. A, 84:33-38, Jan., 1962.

There are determined, for several cell temperatures, current-voltage characterisucs of silicon solar cells cooled by conduction or convection at radiation levels up to 60 langleys per minute. Maximum power output noted is approximately 65 milliwatts per sq. cm. The use of cells as flux measuring devices is noted.

3264
Space Technology Laboratories, Inc., Los Angeles, Calif. CHARGED PARTICLE RADIATION DAMAGE IN SEMICONDUCTORS. I EXPERIMENTAL PROTON IRRADIATION OF SOLAR CELLS. Final Report. 45p., Sept. 15, 1961. (Contract NAS-5 613).

This study compares the effects of proton

over the entire layer and the optimum depth for occurrence of the p-n junction in the photoconverter is determined. Data are presented on the change of open-circuit voltage, short-circuit current, maximum power, and resistance of the doped layer as a function of its gradual etching.

3. Compound Semiconductors

3270
Armour Research Foundation, Chicago, Ill. INVESTIGATION OF SINGLE ENERGY GAP SOLAR CELL MATERIAL, by R. J. Robinson. 2 issues, June, Oct. 1961. (Tech. Summary Rept. 2 and Final Rept.) (Rept. ARF-1175-10; 1175-15) (Contract DA 36-039-sc-87381) (AD-263 861; 274 136).

The program has been devoted to raising the state of the art of cadmium telluride as a useful semiconductor for device applications, and specifically, for solar cell applications.

3271
Cermak, K. and Horak, J. PHOTOVOLTAIC EFFECT IN A THIN FILM OF CADMIUM TELLURIDE. Czechoslov. J. Phys., 11: 141-148, 1961.

In Czechoslovakian. Abs. in Chem. Abs. 55:18339, 1961.

3272
Eagle-Picher Co. Chemicals and Metals Division, Joplin, Mo. INVESTIGATION OF INTEGRALLY COMPOSED VARIABLE ENERGY GAP PHOTOVOLTAIC SOLAR ENERGY CONVERTER, by L. E. Stone and W. E. Medcalf. 2 issues, Jly. 1961, Jan. 1962. (Semiannual Tech. Repts. 1, 2) (AD-264 302, 270 118) (Contract DA36-039-sc-87408).

A study is reported on the feasibility of the variable gap solar cell made from an alloy of GaAs and GaP in which the cell surface is principally of GaP forming a "window" of higher band gap then the GaAs portion.

3273
Gobat, A. R., Lamorte, M. F. and McIver, G. W. CHARACTERISTICS OF HIGH-CONVERSION EFFICIENCY GALLIUM-ARSENIDE SOLAR CELLS. Inst. Radio Engrs. Trans. MIL-6:20-27, figs., Jan. 1962.

Gallium-arsenide solar cells having conversion-efficiency values greater than 11 per cent are described. Crystalline properties of gallium arsenide are discussed, and cell design considerations are given. Gallium arsenide provides several advantages over silicon in the fabrication of high-efficiency cells having improved temperature characteristics and higher radiation-resistance properties. Typical cell characteristics are presented and compared with those of silicon cells. In addition, data are given to show the effects on gallium arsenide cells of incident solar energy, temperature, radiation, and life.

3274
Goryunova, N. A. CHEMISTRY OF DIAMOND-LIKE SEMICONDUCTORS. Zhurn. Vsesoyuz. Khim. Obshchestva im D. I. Mendeleeva 5:522-534, 1960.

In Russian. Uses of compounds as infrared detectors, amplifiers, rectifiers, solar batteries, etc. are discussed. For detailed abstract see Am. Ceram. Soc. J. 45:13, 1962.

3275
Inokuchi, Hiroo and Akamatu, Hideo. ELECTRICAL CONDUCTIVITY OF ORGANIC SEMICONDUCTORS. In Solid State Physics. Advances in Research and Applications, ed. by Frederick Seitz, and David Turnbull, vl. 12, p. 93-148, New York, Academic Press, 1961.

Among the topics discussed is photoelectric phenomena(photoconductivity and photovoltaic effect).

3276
Martinuzzi, Santo. THIN SILICES OF GALLIUM ARSENIDE FOR SOLAR BATTERIES. Acad Sci. Paris. Compt. Rend. 253:1157-1159, 1961.

In French. Electro-conduction measurements and infrared absorption are reported.

3277
Massachusetts Institute of Technology. Department of Electrical Engineering, Electronic Systems Laboratory, Cambridge, Mass. PREPARATION AND PHOTOVOLTAIC PROPERTIES OF VACUUM-DEPOSITED GOLD-BISMUTH OXIDE-GOLD

bombardment of solar cells observed in many experiments at proton energies of 740 Mev, 450 Mev, 400 Mev, and 20.5 Mev. Comparison of a variety of solar cells at each energy is included in order to study the effects of solar cell charactetistics on radiation resistance.

3265
Space Technology Laboratories, Inc., Los Angeles, Calif.
ESTIMATE OF SPACE RADIATION EFFECTS ON SATELLITE SOLAR CELL POWER SUPPLIES, by J.M. Denney and others. 20p., Oct. 20, 1961. (EM 10 21, MR-13).

Charged particle intensity and energy distribution at the heart of the inner and outer Van Allen belts is compared with the experimentally determined radiation sensitivity of silicon solar cells. Energy dependence of the radiation damage and solar cell characteristics is included in the lifetime estimate of spacecraft solar cells. Use of charged particle range energy relations and the differential intensity of the Van Allen radiation results in an estimated effectiveness of thin protective shields. Comparative advantages of thin shields, advanced cell designs, solar efficiency, and solar cell system over design are discussed with respect to radiation resistance of spacecraft power supplies.

3266
Subashiev, V.K. and Pedyash, E.M. ENERGY DIAGRAM OF A REAL SILICON PHOTOCELL. Fiz. Tverdogo Tela 2:213-220, 1960.

In Russian. Transl. in Soviet Phys. Tech. Phys. 2:194-201, 1960.

A means is described of constructing the energy diagram of a real photocell with its carrier concentration, under equilibrium conditions, utilizing experimental data obtained from measurements on the photocell and on the starting material, and parameters characterizing the particular method of preparation of the photocell. The diagrams of two Si photocells obtained by diffusion of Sb in p-type Si are presented to illustrate the necessity for considering the field and the potential drop in the diffusion layers during analysis of the work of such photocells.

3267
Transitron Electronic Corp., Wakefield, Mass.
HIGH EFFICIENCY SILICON SOLAR CELLS, by P.A. Berman. 38p., illus., June 30, 1961. (Semiannual Tech. Summary Rept. 4) (Contract DA36-039-sc-85250) (AD-264-906).

Major effort was placed on the fabrication of high efficiency n on p solar cells by processes which are amenable to production. The investigation into the radiation resistant properties of this cell structure was limited to one set of experiments using 2 Mev electrons as the bombarding particles. The fabrication investigation concerned itself with junction studies, surface studies (upper surface), methods of grid deposition, and diffusion studies. Spectral and current-voltage characteristics of n on p cells were compared with those of p on n cells.

3268
Valdman, Henri. PREPARATION AND STUDY OF HIGH-YIELD SILICON SOLAR CELLS. Acad. Sci. Paris. Compt. Rend., 252: 246-248, 1961.

In French. The cells were produced by diffusion of P in p-type Si plates, and careful removal of the resulting surface layer. Theoretical and practical advantages over cells conventionally produced by diffusion of B in n-type Si are enumerated, and properties are graphed and tabulated. Conversion of solar to electrical energy is about 14%, which with certain modifications can be increased to 15-16%. (Met. Abs. 29:301, 1961).

3269
Zaitseva, A.K. and Gliberman, A.Ya. STUDY OF DOPANT DISTRIBUTION IN THE SURFACE LAYER OF PHOTOELECTRIC SOLAR ENERGY CONVERTERS MADE FROM n-TYPE SILICON. Fiz. Tverdogo Tela 3:2377-2382, Aug., 1961.

In Russian. Transl. in Soviet Phys. Solid State 3: 1724-1725, Feb., 1962.

A model of a silicon photoconverter in which the p-n junction is obtained by means of thermodiffusion of boron into n-type Si is described. It permits one to conduct a layer by layer study of the diffusion layer up to the depth of occurrence of the p-n junction. From the data of the measurements made on this model, the character of the concentration distribution of the impurity which was diffused in is studied

SANDWICHES, by L. A. Fletcher. 64p., Nov. 1961. (Rept. ESL TM-119) (Contracts AF 33(616)-5489; AF 33(616)-7700).

Techniques for the preparation of bismuth oxide films having reproducible absorption characteristics and for the preparation of photovoltaic gold-bismuth oxide-gold sandwiches by vacuum evaporation are described. The energy band structure of bismuth oxide films was examined by electrical and optical measurements. Qualitative measurements were made of the photovoltaic properties of gold-bismuth oxide-gold sandwiches. These measurements are relied upon to propose a qualitative energy band model for the photovoltaic sandwich.

3278
Nadzhakov, G. and others. THE CHARACTER OF THE CONTACT IN THE PHOTOVOLTAIC TRANSVERSE EFFECT IN EVAPORATED LAYERS OF CdS. Acad. Bulgare Sci. Compt. Rend. 13:15-18, 1960.

In German. Abs. in Chem. Abs. 55:7064, 1961.

3279
Pensak, L. HIGH-VOLTAGE PHOTOVOLTAIC EFFECT. Phys. Rev. 109:601, 1958.

Unusually high photovoltages observed across the ends of vacuum-evaporated films of cadmium telluride are reported. It is concluded that the films consist of large number of junctions whose individual photovoltages add to produce the observed values, which are much greater than the band gap of the material.

3280
Radio Corp. of America, Somerville, N.J. GALLIUM ARSENIDE SOLAR CELLS, REPORT ON ENERGY CONVERSION TEHCNOLOGY, by R. W. Runnels. 66p., June 1961. (ASD Tech. Rept. 61-88) (Contract AF 33(616)6615) (AD-267 038).

Analytical and experimental work and the fabrication techniques employed to make solar cells of GaAs are described. Conversion efficiency data on cells fabricated using a close diffusion system and an open tube carrier-gas system are presented. Preliminary experiments present the parameters by which the space charge recombination is characterized, indicating that the effect of the space charge layer recombination may decrease the photovoltage generated. Parameters remaining the same. It is shown that there is little difference in the theoretical value of conversion efficiency with or without space charge recombination. Calculations of reflectance and graphical evaluation of the collection of carriers resulted in establishing the optimum SiO thickness necessary to achieve maximum short circuit current density. Spectral response curves of cells fabricated from the same crystal, as well as different crystals, and processed together are compared. The spectral response from different diffusion runs, as well as different diffusion systems are compared. Variations of short circuit current density over the cell surface has been investigated in both Si and GaAs cells.

3281
Reynolds, D. C., et al. PHOTOVOLTAIC EFFECT IN CADMIUM SULFIDE CRYSTALS. Phys. Rev., 96:533-534, 1954.

During an investigation of the photoconduction and rectification of CdS crystals, a pronounced photovoltaic effect was observed. From specified arrangement open-circuit voltages of 0.4 v have been measured in direct sunlight and 300 ma cm^{-2} in focused sunlight. Also in Conference on the Use of Solar Energy - The Scientific Basis. Transactions, v. 5:192-216, Tucson, Ariz., Association for Applied Solar Energy, 1955.

3282
Starkiewicz, J. et al. A SINGLE CRYSTAL PHOTODIODE OF LEAD SULFIDE. Phys. Soc. Proc. 70B:258-259, Feb. 1957.

A photovoltaic cell consisting essentially of a p-n junction lying parallel to and a short distance below the surface of a single crystal of lead sulfide is described. The junction is formed by converting the surface of a p-type crystal to n-type by vacuum heat treatment. An emf is generated across the junction when the surface is illuminated. The conversion efficiency for total radiation from a Nernst filament source was found to be 0.3% for an incident intensity of 0.1 watt/cm^2. The time constant of these cells is less than 1μs compared with $\sim$ 100 for conventional photoconductive lead sulfide cells. They may be useful in the study of rapid fluctuations of temperature in the range 150-600°C or in applications where the steady current

drain of a photoconductive cell would be undesirable. Under conditions of good illumination sufficient power is available from the photovoltaic cell to operate a relay directly.

3283
Talley, R. M. and Enright, D. P. PHOTOVOLTAIC EFFECT IN InAs. Phys. Rev., 95: 1092-1094, 1954.

The photovoltaic response in p-n junctions of InAs is reported for radiation of 1 to 10 microns incident on the cell at liquid-nitrogen temperature. There is a sharp peak near 3.5 microns and no response above 4.8 microns. The transmission of InAs at room temperature is reported.

3284
U.S. Air Force. Electronics Technology Laboratory. Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. GALLIUM ARSENIDE SOLAR CELLS, by R. W. Runnels. 66p., June 1961. (ASD TR 61-88).

Development is described of a photovoltaic solar energy converter fabricated from gallium arsenide, and a technique to measure conversion efficiency.

4. Devices

3285
Baron, W. R. THE SILICON SOLAR CELL. Electron. World 66:33-36, illus., Dec. 1961.

A primary power source for the space age, this device makes possible direct, instanteous, and efficient conversion of the sun's energy into useful electric power.

3286
Electro-Optical Systems, Inc., Pasadena, Calif. FEASIBILITY STUDY TOWARD DEVELOPMENT OF RADIATION RESISTANT SOLAR CELL, by S. Kaye. 5 issues, Dec. 1961, Jan., Feb., Apr., May 1962. (Rept. 2080-ML-1, 2, 3, 5, 6) (Contract NAS 7-92).

Work has continued on fabrication of graded base n on p solar cells. The highest efficiency cell so far produced is one of 11.5 percent measured in sunlight at sea level. Increase in efficiency has been due to improvements in the junction diffusion step and also the application of a silicon monoxide coating which has considerably reduced the reflection losses.

3287
GLASS PROTECTS SOLAR CELLS FROM RADIATION. Electron. 35:8, Jan. 5, 1962.

"Analysis of solar cell performance data telemetered from the Explorer XII satellite shows that glass coatings will protect the cells from radiation belts in space, NASA reports.

Four banks of cells were carried. One bank, unprotected, degraded 50% on the first two orbits through the Van Allen belt, another 25% during the remainder of the satellite's 112-day life. Cells protected with 20-mil and 60-mil glass did not degrade and cells with 3-mil coatings degraded about five %.

Among other experiments was one to measure the electron and proton concentrations in the outer Van Allen belt. Electron concentration is a thousand times less than previously thought. There are more protons, but their energy, below 1-Mev, is no hazard to space flight." Entire item quoted.

3288
Howson, R. P., Roberts, D. H. and Wilson, B. L. H. SOME THERMAL CONSIDERATIONS ON THE USE OF SOLAR CELLS. Brit. Inst. Radio Engrs. J., 22:519-525, figs., Dec. 1961.

The dependence of solar cell characteristics on temperature is demonstrated. The radiation balance of solar cells in space is then discussed for different configurations of the cell assembly and for different orbits and it is shown that these can have considerable influence. Means of achieving temperature stabilization are described. The value of surface coatings is discussed briefly.

3289
Luft, Werner. STATIONERY SILICON SOLAR CELL CONVERTER CALCULATIONS. Solar En. 6:27-32, Jan.-Mar. 1962.

The power output from a silicon solar cell converter depends on its geographical location. The article shows how the required amount of silicon solar cells for a given power output is determined for any place on the globe; the optimum angle to which a stationery converter should be tilted; and how the required storage device capacity for continuous operation is calculated.

3290
Simpson, Robert. SOLAR CELL DIRECTS CARD FEED ON PRINTER. Electron. 35: 70, 73, illus., Jan. 12, 1962.

The assembly of an IBM printer is illustrated and described and the advantages of using a solar cell is pointed out.

3291
SOLAR CELL MATCHED TO SPACE SUNLIGHT. Mach. Design, 33:10, Aug. 17, 1961.

A brief article gives a few details of the blue space solar cell, a new type recently developed which, reportedly, will deliver more electrical power to satellite instruments than any other cell of the same size. It will have a longer useful life also.

3292
SOLAR CELLS IMPROVE PYROMETER PRECISION. Eng. 192:362-363, Sept. 15, 1961.

Use has been found for the silicon solar cell in connection with industrial radiation pyrometry. It improves the sensitivity, the response-time, and the accuracy.

3293
SOLAR CELLS USED IN COMPUTER UNIT. Sci. Dig. 50:86, Dec. 1961.

A brief article announces the first commercial application of solar cell units for card reading units of computer systems.

3294
Strand, H. P. LIGHT POWERS THIS ELECTRIC MOTOR. Popular Mech., 116:202-203, illus. Nov. 1961.

A small motor is described which is useful for teaching the principles of direct conversion of light to electricity. It can be made from a kit of listed materials. Powered by two series-connected silicon solar cells as a light battery, the motor drives a propellar attached to its shaft at high speed when placed in bright sunlight or artificial light. The solar battery which is the power source develops a maximum of about 1 volt and around 100 milliamperes.

3295
Torrey, V. SUNSHINE BECOMES ELECTRICITY. Popular Sci., 165:71-72, Jly. 1954.
The Bell solar battery is described.

5. Systems

3296
Cook, E. F. POWER FROM THE SUN. Army 11:39-43, illus., Apr. 1961.

Solar cells may lighten the soldier's load, give him better communications, and greater mobility. The usefulness of solar cells for military purposes and their development especially for satellites is discussed.

3297
EIN SONENELEKTRISCH ANGETRIEBENER KRAFT-WAGEN. (AN AUTOMOBILE DRIVEN BY SOLAR ELECTRICITY). Radio u. Fernsehen 10:558, Sept. 2, 1961.

In German. "An automobile driven by solar electricity has been demonstrated in USSR. Its top consists of several thousand high-grade photoelectric cells which produce from sunlight enough energy to operate the electric motor of the car. The electric energy is stored in an equally new battery system which allows the car to be driven for some time when the sun is not shining." Transl. of entire item.

3298
Electro-Optical Systems, Pasadena, Calif. INVESTIGATION OF SOLAR CONCENTRATING PHOTOVOLTAIC POWER GENERATORS, by D. H. McClelland. 348p., illus., May 1961. (Interim Summary Rept.) (Rept. 530-IR-1) (WADD TR 60-849) (Contract AF33(616)7346) (AD-264 989).

The results are presented of Phase I of a program to study and evaluate the use of concentration with photovoltaic power generators. The program is divided into three parts: (1) preliminary investigation of all factors relating to the use of concentration with photovoltaic power generators; (2) technical analysis of photovoltaic power generators in the power range from 500 to 1500 watts; and (3) design, fabrication, and test of a 50-watt scale model of the 1500 watt power systems. It was concluded from the work conducted to date that the use of concentration with photovoltaic power systems has important advantages at the present time and will become even more useful in the near future as better solar cell filters and fabrication techniques are developed.

3299
Fischell, R. E. THE TRAAC SATELLITE. APL Tech. Dig. 1:3-9, illus., Jan.-Feb. 1962.

The TRAAC satellite was primarily an experiment to use the earth's gravitational field for controlling the attitude of an orbiting satellite. The electrical power system consists of solar cells charging nickel-cadmium secondary batteries. The minimum power-generating capability of the satellite in the orbits of least illumination is approximately 16 watts.

3300
Getler, Michael. LAUNCH DATE NEARS FOR FIRST TELSTAR. Missiles and Rockets, 10:22-23, illus., Feb. 19, 1962.

AT&T's space communication satellite will test system feasibility, carry important radiation package. Power for the electronics will be directly supplied by 20 rechargeable nickel-cadmium cells. The 3600 solar cells which dot the skin of the satellite will provide the charge for the nickel-cadmium cells. Initial solar-cell conversion output is expected to be 15 watts. Due to anticipated radiation and meteroid damage, this figure will probably drop to about 11 1/2 watts after about a year in orbit.

The solar cells will be mounted on a ceramic base with a platinum frame and will be shielded from electron bombardment by a clear, laboratory sapphire material.

3301
Herchakowski, A. and Kittle, E. DESIGN CONSIDERATIONS FOR A PHOTOVOLTAIC CONVERSION SYSTEM USING CONCENTRATORS. In Power Sources Conference. Proceedings, 15th, 1961, p. 120-124, figs., Red Bank, N. J. PSC Publications Committee, 1961.

An approach to the reduction of the high cost per watt of photovoltaic solar energy conversion systems concerns the investitigation of solar concentrators to increase the power output per unit cell area. This approch is discussed in two phases. Phase one covers performance characteritics of solar cells at higher intensities and temperatures. Phase two covers an analysis of optimum concentration ratios and design parameters for a flat plate type of concentrator.

3302
Johns Hopkins University. Applied Physics Laboratory, Silver Spring, Md. DESIGN AND DEVELOPMENT OF THE TRANSIT NAVIGATIONAL SATELLITE, by M. A. Schreiber and T. Wyatt. 55p., May 1961. (CM-994A) (Contract Nord-7386).

The power supply which includes utilization of a solar generator is described, p. 14-21.

3303
NIMBUS SATELLITE FOR 1962. Sci. News Ltr. 80:366, Dec. 2, 1961.

Two large paddles of solar cells will convert the sun's energy into electrical power to operate the satellite's instrumentation and supply power to storage batteries for continued operating during periods of darkness.

3304
Rosenzweig, W. SILICON SOLAR CELLS AS VERSATILE RADIATION DOSIMETERS. Rev. Sci. Instr., 33:379-380, Mar. 1962.

The purpose of this note is to point out the utility and simplicity of operation of silicon solar cells as dosimeters or monitors of high intensity radiation.

3305
SILICON SOLAR BATTERIES AND PHOTOCELLS. Radio & Electron. Comp. 1:369, May 1960.

Several types of cells are mentioned but chiefly the photovoltaic cell which has been developed, using single crystal silicon containing a p-n junction. The process for making this cell is briefly outlined, and its uses indicated.

3306
SOLAR BATTERIES IN WEATHER-EYE SATELLITE. Radio & Electron. Comp., 1:419, illus., June 1960.

Details, in brief, are given for the first application in history of solar cells as a source of power for miniaturized television equipment in The Tiros weather-eye satellite.

3307
SOLAR CELL INSTALLATIONS. TRINITY

HOUSE DEVELOPMENT FOR MARINE BUOY LIGHTING. Radio & Electron. Comp. 2:776, 780, illus., Oct., 1961.

Application of the silicon photo-voltaic cell to marine buoy lighting is under investigation and the first fully-equipped installation can be available for operation before the end of 1963. Some details of the research and problems involved are given.

3308
Spectrolab, Inc., N. Hollywood, Calif. INVESTIGATION OF OPTICAL COATINGS FOR SOLAR CELLS, by A. E. Mann. 2 issues, June, Dec. 1960. (Semiannual Repts. 1 and 2) (Contract DA 36-039-sc-85284) (AD 271 599; AD 271 358).

The evaluation of state-of-the-art solar cell coatings and advances towards the idealized window coatings are discussed.

3309
Snyder, N. W. SOLAR-CELL POWER SYSTEMS FOR SPACE VEHICLES. Inst. Radio Engrs. Trans. MIL-6:84-91, illus., Jan., 1962.

Silicon (p-on-n) solar cells have been the energy converter between solar energy and electricity with the storage of energy being accomplished by the nickel-cadmium battery. This paper will be directed toward the general engineering considerations applied to space vehicles.

3310
U. S. Air Force. Electronics Technology Laboratory. Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. AN INVESTIGATION OF SOLAR CELL CAPABILITIES FOR SATELLITE APPLICATIONS, by R. W. Runnels. 45p., Nov. 1961. (ASD Tech. Rept. 61-334).

Study of the physical and electrical characteristics of solar cells constructed of several different materials by different manufacturers. The solar spectrum as found outside the atmosphere at the Earth's mean orbit is presented. Energy levels in the vicinity of Earth, Mars, and Venus are given, as well as the thermal and pressure conditions expected. The radiation of the Van Allen belts and the effects upon the various types of cells are discussed. Several techniques for solar simulation are described. (Intern. Aerospace Abs. 2: 62-4811, May 1962).

3311
Wolf, M. THE PRESENT STATE-OF-THE-ART OF PHOTOVOLTAIC SOLAR ENERGY CONVERSION. Solar En. 5:83-94, figs., Jly./Sept. 1961.

The present state-of-the-art in photovoltaic solar energy conversion, in particular, as applied for space vehicle power supplies is summarized. Past and future development goals are lower weight-to-power and cost-to-power ratios, higher reliability, and increased useful lifetimes. Recent improvements introduced in the present standard device, namely, the silicon solar cell, are discussed. They include application of metallic grids for the reduction of series resistance and change of the p-layer thickness for improved spectral response. Further, attempts to develop methods for preparing large area and thin film silicon solar devices are reviewed and finally a survey is given of the progress made in the application of other semiconductor materials to solar photovoltaic energy conversion. Here the work on cadmium sulphide solar cells stands out due to the achievement of solar conversion efficiencies of up to 4-1/2% on thin film cells.

B. Photoemissive

3312
Borzyak, P. G. THE BaO-ADSORPTION EFFECT ON THE WORK FUNCTION AND PHOTOELECTRIC EMISSION OF SEMICONDUCTORS. In International Conference on Semiconductor Physics, Prague 1960. Proceedings, p. 570-573, New York, Academic Press, 1961.

The work function change of several semiconductors during adsorption of dipolar mols. of BaO and the effect of this change on photoelectron emission was studied and discussed.

3313
National Research Corp., Cambridge, Mass. PHOTOEMISSIVE SOLAR CONVERTER, by M. P. Hnilicka and others. 63p., Jly. 1961. (ASD-TR 61-80) (Contract AF 33(616)-7534) (AD-267 037).

This is a study of the characteristics of a photoemissive solar energy converter. The device consists of a perforated sheet of dielectric material coated on one side with a conductor having a low work function.

3314
Sorokin, O. M. PHOTOELECTRONIC EMISSION FROM MERCURY TELLURIDE. Fiz. Tverdogo Tela 2:2349-2353, Oct., 1960.

In Russian. Transl. in Soviet Phys. Solid State 2:2091-2095, figs., Apr. 1961.

In recent years because of their importance in certain practical applications, a great deal of attention has been devoted to investigating the electrical properties of the intermetallic compounds possessing zinc blende structure.

The present paper deals with the external photoeffect of mercury telluride (HgTe), which is one of these compounds. The experimental arrangement and method of specimen preparation (coarsely crystalline blocks and evaporated layers) are similar to those described in an earlier paper. Curves are given showing the spectral distribution of the photoemission and the photoelectron energy distribution at different wavelengths. These curves are compared with similar curves for metals and semiconductors.

3315
Westinghouse Electric Corp., Baltimore, Md. PHOTOEMISSION SOLAR ENERGY CONVERTER. 2 issues, Jly. 15, 1960, Jan. 1, 1961. (Semiannual Repts. 2, 3) (Contract DA36-039-sc-85248) (AD-264 828, AD-263 107).

Experimental results using the WX-3964 photogenerator are presented, showing that one tube, having a relatively wide spacing of 70mils, supplied output power of over 125 microwatts at an efficiency of 0.01 percent. A description of an experiment in the bell-jar processing station is presented herein, and the operation of the automatic readout experiment is described. Steps leading to the manufacture and processing of the anode and photocathode are described, as well as the construction of the WX-4209, a thin glass-sandwich photogenerator. Changes in processes and procedures are noted; and work leading to an equivalent circuit for the photogenerator is given.

3316
Young, J. W. SUNLIGHT METERS HELP DISPATCHER FORECAST LOAD: INDICATING MICROAMMETERS WITH POWER SOURCE FROM SOLAR BATTERIES. Elec. World 156:78-79, illus., Aug. 28, 1961.

The meters are indicating microammeters with a power source from six solar batteries. Each solar battery is a self-generating, selenium photocell and sun battery.

C. High Energy Processes

3317
Bakhyshov, A. E. and Abdullaev, G. B. PHOTOELECTRIC PROPERTIES OF THE SEMICONDUCTORS Tl_2Se-Se AND InSe-Se EXPOSED TO X-RAYS. Akad. Nauk Azerb. SSR. Dokl. 16:437-441, 1960.

In Russian. Abs. in Chem. Abs. 55:7065, 1961.

V. MAGNETOHYDRODYNAMICS

A. General Information

3318
Coombe, R. A. ELECTRIC POWER BY "MAGNETOHYDRODYNAMICS". New Scientist 13:254-256, Feb. 1, 1962.

Widespread application of this principle - generation of electricity by the action of a magnet on a jet of hot gas - appears to be only a matter of time. It offers much greater efficiency than the conventional turbine generator. Research is being done in many countries on the problems to be solved, which are here discussed.

3319
General Electric Co., Space Sciences Laboratory. Missile and Space Vehicles Department., Valley Forge, Pa. STUDY OF ELECTRICAL ENERGY CONVERSION SYSTEMS, July 1960-August 1961, by A. Sherman and G. W. Sutton. 107p., Sept. 1961. (ASD TR 61-379) (Contract AF33(616)-7539) (AD-269 213).

Investigations on MHD and EHD power generation are reported.

3320
General Electric Co., Space Sciences Laboratory. Valley Forge, Pa. THEORETICAL STUDY OF THE ELECTROHYDRODYNAMIC GENERATOR, by J. M. Smith. 24p., Nov. 1961. (Tech.

Info. Ser. R61SD192) (Contract AF 33(616) 7539).

A theoretical analysis is presented of an electric power generator based on the principle of the Van de Graff generator, the difference being that the charge is transported in a moving gas rather than on a moving belt.

3321
Harris, D.J. DIRECT GENERATION OF ELECTRIC POWER FROM A HIGH-VELOCITY GAS JET. Elec. Eng. 80:974-978, Dec. 1961.

The possibility of generating electric power by the electromagnetic braking of a high-velocity gas jet is discussed. Outstanding problems are assessed and suggestions are put forward for the solution of some of them, but the need for more research is emphasized.

3322
Kantrowitz, A.R., and others. THE MAGNETOHYDRODYNAMIC POWER GENERATOR --BASIC PRINCIPLES, STATE OF THE ART, AND AREAS OF APPLICATION. Inst. Radio Engrs. Trans. MIL-6:78-83, figs., Jan. 1962.

The paper opens with a review and discussion of the basic principles of MHD power generation. After a derivation of the basic MHD-generator flow equations a brief synopsis of losses in a MHD generator is given. There follows a brief statement of the state of the art in MHD-generator development at the Avco-Everett Research Laboratory. Finally, some potential applications of MHD are suggested. These applications lie in the areas of central station power generations, shipboard propulsion, limited duration, high-power units, and energy storage and discharge in some ranges now covered by capacitor and inductive devices.

3323
Klein, Siegfried, A DIRECT THERMAL-TO-ELECTRIC ENERGY CONVERTER. Acad. Sci. Paris. Compt. Rend. 251:2492-2494, Nov. 28, 1960.

In French. This note gives further results on a scheme previously described A jet of gas, ionized in a flame, is passed through two consecutive metal tubes, insulated by a short length of glass tubing. It is found that provided there is a temperature gradient in the direction of motion, a significant p.d. is established between the two tubes. This gradient was measured under various load conditions by probes inserted in the glass-tube insulator. The qualitative results obtained are discussed. (Sci. Abs. 64A:7020, 1961).

3324
Marks Polarized Corp., Whitestone, N.Y. THE CONVERSION OF HEAT TO ELECTRICAL POWER BY MEANS OF A CHARGED AEROSOL. 2 issues, Nov. 4, 1960, Mar. 9, 1961. (Quart. Repts. 1, 2) (Contract NOw-60-0831-c).

Feasibility of the conversion of heat to electric power through the medium of a charged aerosol is experimentally demonstrated.

3325
Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass. MAGNETOHYDRODYNAMICS AND ENERGY CONVERSION. 4 issues, Jan., Sept. Dec., 1961, Feb. 1962. (Tech. Prog. Repts. 1, 4, 5, 6) (Contract AF33(616)7624).

Various experimental studies are reported.

3326
Massachusetts Institute of Technology. Research Laboratory of Electronics, Cambridge, Mass. QUARTERLY PROGRESS REPORT NO. 62. 233p., Oct. 15, 1961. (Contract DA 36-039-sc-78108).

Aids for the analysis of thermionic energy converters, p. 1-3; Plasma magnetohydrodynamics and energy conversion, p. 49-67.

3327
Thornton, J.A. MHD - TECHNICAL TROIKA TIMED FOR LIFT-OFF. Res. Devlpmt. 13:5-9, Feb. 1962.

An explanation is given of magnetohydrodynamics in terms understandable to the layman. Basic principles are outlined, simultaneous equations are explained, experimental work (although still in its infancy) is mentioned, and applications and use in space vehicles are listed. A brief paragraph is devoted to power generation.

B. Principles

3328
Avco-Everett Research Laboratory, Everett, Mass.
BASIC STUDIES IN MAGNETOHYDRODYNAMICS. May 1, 1957 - October 31, 1961. 28p., 1961. (Final Rept.) (AFOSR 1782) (Contract AF 49(638)-61).

Research was directed toward obtaining a basic understanding of magnetohydrodynamics. The initial studies led to three possible applications for magnetohydrodynamics which in turn led to three categories of research. The first application appeared in connection with the problem of high-altitude, very high velocity flight which we call flight magnetohydrodynamics. The second application was plasma propulsion. The third category was the production of a very high temperature collision-free plasma.

3329
General Electric Co. Missile & Space Vehicle Dept. Space Science Laboratory, Philadelphia, Pa.
THE COMBINED EFFECT OF TENSOR CONDUCTIVITY AND VISCOSITY ON AN MHD GENERATOR WITH SEGMENTED ELECTRODES, by A. Sherman and G. W. Sutton. 25 p., June 1961. (Rept. R61D100) (AFOSR 687).

Analysis of the combined effects of viscosity, transverse velocities, and the elimination of the Hall currents in a channel of finite height, considering the Reynolds number to be arbitrary. Results are applied to the calculation of the efficiency of the generator, and can be used in determining the performance characteristics of an MHD plasma accelerator. End effects and effects near the electrodes are neglected. (Intern. Aerospace Abs. 1:61-8208).

3330
Sodha, M. S. MAGNETOHYDRODYNAMICS. Indus. Res. 3:56-60, Oct., 1961.

Discussion of the principles of operation, construction, and main components of magnetohydrodynamic generators. Several closed- and open-cycle systems are discussed, and their estimated efficiencies are compared. The possiblity of constructing an MHD generator having an a.c. output are considered, as are the limitations of channel-wall and cathode materials. (Intern. Aerospace Abs. 61-10235).

3331
Sutton, G. W. MHD ENGINE USES TRAVELING WAVE. Electron. 35:26-27, Apr. 13, 1962.

New data on applications of magnetohydrodynamics to flight and power conversion is reported as an outcome of the Third Annual Symposium of Magnetohydrodynamics.

3332
SYMPOSIUM ON MAGNETOHYDRODYNAMICS, 5th, Palo Alto, 1960. Radiation and Waves in Plasmas, ed. by Morton Mitchner. 156p., Stanford, Calif., Stanford University Press, 1961.

Includes 7 papers. For analysis of contents of one paper, see entry for Kino, G. S.

C. Plasma Properties

3333
Conway, W. R. THERMAL AND ELECTRICAL CONDUCTIVITIES IN A PLASMA. A PHENOMENOLOGICAL APPROACH. 31p., Tallahassee, Fla., Florida State University, Aug., 1961.

Thesis, A phenomenological approach was developed for the problem of the evaluation of the conductivities, both thermal and electric, in a plasma. A time of relaxation in the transport process was applied. The collision term of the basic transport equation was replaced by terms which represent displacements in velocity space from an equilibrium distribution, toward which the plasma tends to return. The phenomenological method results in expressions which fulfill the physical requirements of dependence on temperature, particle concentration, and degree of ionization. (Nuclear Sci. Abs. 16:3758, Feb. 15, 1962).

3334
Kino, G. S. THERMAL GENERATION OF A FULLY IONIZED CESIUM PLASMA. In Symposium on Magnetohydrodynamic, 5th, Palo Alto, 1960. Radiation and Waves in Plasmas, ed. by Morton Mitchner, p. 119-137, Stanford, Calif., Stanford University Press, 1961.

Experiments are described which are aimed

at producing a highly ionized plasma in which electrons and ions are in thermal equilibrium, by using resonance ionization of cesium at a tungsten surface.

D. Devices

3335
AiResearch Manufacturing Co., Los Angles, Calif.
VORTEX MAGNETOHYDRODYNAMIC GENERATOR DESIGN STUDY, by E. Knoernschild and H. G. Starck. 193p., Nov. 1961. (ASD TR 61 380) (Contract AF33(616)-7807) (AD-270 479).

Analytical studies are presented of the processes involved in the generation of electric power in a vortex MHD generator; plasma generation; heat transfer; and materials.

3336
General Electric Co., Space Sciences Laboratory, Valley Forge, Pa.
VELOCITY PROFILES AND EFFICIENCY OF MHD GENERATORS WITH SEGMENTED ELECTRODES, by H. Yeh and G. W. Sutton. 30p., Sept. 15, 1961. (AFOSR 1595, R61SD 150) (Contract AF49(638)-914).

This report is concerned with the power output and efficiency of a MHD generator with segmented electrodes when both the tensor conductivity and the non-uniform fluid velocity across the channel are taken into consideration.

3337
Harris, L. P. and Cobine, J. D. THE SIGNIFICANCE OF THE HALL EFFECT FOR THREE MHD GENERATOR CONFIGURATIONS. J. Eng. for Power (ASME Trans.) 83:392-396, figs., Oct., 1961.

Analyses are presented for the influence of the Hall effect on electrical terminal characteristics, generated power per unit volume, pressure gradient, and generator efficiency in three configurations for MHD generators. The results indicate that desirable generator characteristics can be attained when the Hall effect is either negligible or dominant.

3338
Pain, H. J. and Smy, P. R. EXPERIMENTS ON POWER GENERATION FROM A MOVING PLASMA. J. Fluid Mech., 10 (Pt. 1):51-64, Feb. 1961.

A report of experiments into the generation of electrical power from a moving plasma using a pulsed system. Power was extracted from the plasma for periods of about 100 μsec, i.e., the duration of plasma flow through the electrode and magnetic field system (Index Aero. 17: 61, Apr. 1961).

3339
PERMANENT ELECTRODES FOR MAGNETOHYDRODYNAMIC POWER GENERATION. Nature 193:467-468, Feb. 3, 1962.

Some preliminary results are reported which suggest a possible way in which permanent electrodes may be obtained. Cooled metal surfaces are used on which a thin layer of carbon is deposited from the gas stream. As this layer is ablated away more carbon may be deposited to maintain an equilibrium thickness, so that the electrode surface is continuously replaced.

3340
Smy, P. R. ALTERNATING CURRENT MAGNETOHYDRODYNAMIC GENERATOR. J. Appl. Phys. 32: 1946-1951, Oct., 1961.

The design criteria of a proposed ac magnetohydrodynamic (mhd) generator is discussed. It is found that electrical losses to the moving fluid are serious unless the duct length-to-width ratio is greater than about 30. Two developments of such a generator are suggested. The first would provide a solution to the problem of power output from a segmented-electrode generator. The second development, that of capactive power transfer at the electrode-fluid interface, would have many benefits, but its application is found to be severely restricted by the limited dielectric strength of materials. (Sci. Abs. 65A:236, Jan. 1962).

3341
Way, Stewart, etal. EXPERIMENTS WITH MHD POWER GENERATION. J. Eng. for Power (ASME Trans. A):83:397-408, figs., Oct. 1961.

This paper (paper 60-WA-328) is a report on the development of an experimental MHD electrical generator which derives its energy from the combustion of a liquid fuel and oxygen. The fuel burned is a number 2 distillate oil in which a soluble potassium octoate is mixed to increase the degree of

thermal ionization in the product gas. The actual generating volume is approximately 125 cubic inches and the rating of 10 KW has been exceeded.

The paper describes some of the broad construction features of the generator and problems arising during its operation. Other sections deal with the fuel and combustion systems, fuel characteristics, and the electrical and magnetic aspects. The theory of MHD power generation in a uniform duct is presented. Results of the experiments are presented and actual performance compared with theory. The paper is illustrated with photographs and sketches.

VII. ELECTROCHEMICAL PROCESSES

3342
PROVIDING THE CURRENT IN FUTURE CARS. Eng., 192:168, Aug. 11, 1961.

A brief review is given of the performance and future possibilities of lead-acid batteries, the nickel-cadmium (or alkaline) battery, solar batteries, and fuel cells for engine-starting and/or driving of cars. A graph is shown of the energy outputs from the above types of batteries. (Fuel Abs. & Current Titles 2:6784, 1961).

A. Fuel Cells

1. General Information

3343
Alexander, George. FUEL CELL DEVELOPMENT PUSHED FOR SPACE. Aviat. Wk. and Space Tech. 76:54-55, 59, 61, 63, illus., Apr. 9, 1962.

Fuel cells, in general are described, and some of the problems to be faced in development of the fuel cells for Gemini and Apollo. For the two-man Gemini capsule the cell is of the ion-exchange membrane- or solid electrolyte-type. For the three man Apollo spacecraft the cell features a dual membrane, electrodes, separate catalyst and a liquid acid electrolyte.

3344
AMMONIA: NEWEST FUEL FOR FUEL CELLS. Mach. Design 33:6, Oct. 12, 1961.

Brief mention is made of experiments with a low cost ammonia cell, the electrode material for which is porous carbon, and the electrolyte-concentrated potassium hydroxide.

3345
Beller, William. FUEL CELLS LEAD APOLLO-GEMINI FIELD. Missiles and Rockets, 10:24-25, Apr. 9, 1962.

It is indicated that fuel cells and solar cells are the likeliest contenders for back-up systems. All possible systems are however, being studied. These include thermionic, thermoelectric and cryogenic systems. In the Cryhocycle, which is illustrated, energy is extracted from waste heat and converted into useful power.

3346
Bloch-Chaude, Odile. RECENT DEVELOPMENTS IN FUEL CELLS. Soc. Chim. France, Bull., p. 2447-2452, 1961.

In French. A review with 43 references.

3347
CHEMICAL ENERGY - ELECTRICAL POWER SOURCE. Indus. Labs. 10:53, 1959.

Nontechnical article giving description of Lockheed's fuel cell or, rather, a description of what it might do. No specific information is given other than 100% fuel utilization, 70% energy conversion. Fuel cell being developed is designed to produce 100 watt-hours per pound.

3348
Danckwerts, P.V. FUEL CELLS. Indus. Chem., 28:99-102, Mar. 1952.

This review article defines a fuel cell as "a primary electrochemical cell in which electric power is produced directly by the oxidation of some kind of fuel, such as carbon, carbon monoxide or hydrogen". The article is concerned with the background of fuel cells and, as such, has headings with titles: Theoretical Possibilities, Electrochemical Cells, Polarization, Design of Fuel Cells, The Mond Langer Cell, and Use of Solid Electrolyte. Five references are listed.

The statement is made that the theoretical efficiency of an advanced type steam engine is 70% at 1450°R but, that in practice, 30% is not exceeded. The efficiency of a diesel engine may be as high as 35%, and

of a gas turbine, 20%. Since the fuel cell is not a heat engine, the efficiency is not limited by the Carnot cycle. The efficiency of a carbon oxygen cell may be as high as 124%, using the author's definition of efficiency. The statement is made that the conversion of fuels to gaseous products, before their use in a fuel cell, will cause a loss in available energy.

3349
Douglas, D.L. and Liebhafsky, H.A. FUEL CELLS MAY PROVIDE ON IMPORTANT SOURCE OF POWER. Gen.Elec.Rev., no. 61, p.40-41, 1958.

This article discusses fuel cells from a qualitative aspect. The theory of the fuel cell is presented in non-technical language. It is stated that the fuel cell escapes Carnot cycle limitations because it never converts heat directly into work. It converts chemical energy into electrical energy. A fuel cell or any other battery can operate isothermally; devices subject to Carnot efficiency, cannot.

3350
Flynn, J.D. FUEL CELLS AND THEIR EFFECTS ON UTILITIES. Elec.Eng., 80: 828-831, Nov.1961.

Fuel cells will become practical initially in watt sizes, then in kilowatt and in megawatt sizes. As their development advances into the kilowatt range, they will stimulate brisk competition among the oil industry and electric and gas utilities for the opportunities of being the "single energy" source. When the megawatt size is reached, they will favor electric utilities over other energy suppliers.

3351
Fox, H.W. and Roberts, R. FUEL CELLS. Inst.Radio Engrs.Trans. MIL-6:46-57, figs., Jan.1962.

A comparison is drawn between the theoretical efficiencies of heat engines and fuel cells in the conversion of chemical to electrical energy. The electrochemical principles governing the operation of fuel cells are discussed. Short descriptions, including performance curves, are given of a few selected fuel-cell types including low-, intermediate-, and high-temperature cells, and redox and regenerative cells. An example is given of a rough calculation of battery and fuel weight and volume for a given power level and total energy demand.

3352
FUEL CELL CONSIDERED AS LOCOMOTIVE POWER SOURCE. Elec.Eng., 81:37, Jan.1962.

The fuel cell, or fuel battery was considered as a possible source of power by R.M. Coultas, in a talk in which fuel economy was discussed.

3353
FUEL CELL ENTRY. Chem.Wk. no.79, p.40, Sept.22,1956.

A brief article mentioning several fuel cell research projects and progress made since Sir William Grove devised the first fuel cell, in 1839.

3354
FUEL CELLS MAY STAR IN SATELLITE POWER PICTURE. Chem.Eng., 65:30, Dec.29,1958.

Note on fuel cells for satellites and space rockets based on generating electricity directly from chemical reactions with over 80% fuel efficiency. Power output of Lockheed battery 10 times that of car battery per lb. Mention is made of C electrode cell by National Carbon, thermionic converters by General Electric. (Fuel Cell Bib., Mond Nickel Co., 1960).

3355
FUEL CELLS NEAR REALITY. Financial World 113:14, 33, Feb.3,1960.

With many advantages over conventional power sources, fuel cells seem headed for greatly expanded uses, and companies in the vanguard of research may win big rewards.

3356
FUEL CELLS -- WHERE ARE WE NOW? Indus.Eng.Chem., 54:65-68, Jan.1962.

A review based on the recent ACS Symposium.

3357
Grimes, P.G., Fiedler, Bruce and Adam, James. LIQUID ALKALINE FUEL CELLS. In Power Sources Conference. Proceedings, 15th, 1961, p.29-32, illus., Red Bank, N.J., PSC Publications Committee, 1961.

Preliminary investigations are reported of an all-liquid fuel cell system which uses methanol and hydrogen peroxide as fuel and oxidant. Platinum and silver are reasonably selective fuel and oxidant catalysts respectively. The principal product formed in the cell is formate ion.

Characteristics of this fuel cell system allow the use of a simple bipolar electrode construction in the fabrication of cells.

3358
Ishino, T., Tamura, H., and Matsuda, Y. FUEL CELLS. Fuel Soc. Japan J., 40: 165-176, Mar. 1961.

In Japanese. The economic and practical prospects of fuel cells as well as their structures, electrode reactions and features are discussed. Fuel cells are very promising not only as mobile or independent power sources, but also for large power stations if cheaper fuels are to be used in future by the development of the petrolchemical and natural-gas industries. It is also possible that fuel cells will be used as substitutes for electric-power generators, various electric cells and gasoline engines. (Fuel Abs. & Current Titles 2:7612, 1961).

3359
JOINT SYMPOSIA ON FUEL CELLS (BATTERY DIVISION OF ELECTROCHEMICAL SOCIETY WITH CORROSION AND OTHER DIVISIONS). Detroit, Mich. Oct. 1961. EXTENDED ABSTRACTS. Brochure 1961, 161p.

116 abstracts (some several pages long) including sessions on primary and secondary batteries and their properties, fuel electrodes, oxygen electrodes, fuel cells, fused salt corrosion and high temperature fuel cells. The existence of these abstracts is no guarantee that longer corresponding communications will necessarily appear. (Brit. Non-Ferrous Met. Res. Assoc. Bull. note 3337, 1961).

3360
Liebhafsky, H. A. and Grubb, W. T., Jr. THE FUEL CELL IN SPACE. ARS J., 31: 1183-1190, Sept., 1961.

Survey of fuel cell technology for space operations. It is concluded that if the severe reactivity and invariance requirements can be met even moderately well, the device should prove useful on missions too long for primary batteries. Fuel cells should also prove an attractive alternative to secondary batteries on extremely long missions in which fuel can be regenerated by using another form of energy, preferably that of the sun. (Intern. Aerospace Abs. 61-9234).

3361
Liebhafsky, H. A. FUEL CELLS. Intern. Sci. & Tech., 1:54-59, 62, illus., Jan. 1962.

The need for better energy sources has led to an unprecedented amount of R&D in the field of energy conversion. Of the various means for the direct conversion of fuel to electricity, the fuel cell has the highest theoretical efficiency and is furthest advanced toward realizing it. Though many basic problems must be solved before dependable units can be economically mass-produced, the fuel cell promises to come into its own before many years. Already it has powered a tractor and a small car.

3362
Lockheed Aircraft Corp., Missiles and Space Division, Electrochemistry Research Laboratory, Sunnyvale, Calif. BASIC STUDIES ON FUEL CELLS SYSTEMS, May 19 - August 15, 1961. 11p., illus., Aug. 15, 1961. (Quart. Rept. 1) (Contract NOw 60-0738-d).

An eight-cell fuel cell battery for anode catalyst comparative studies in the ammonia -oxygen system has been assembled and operated. Results for this run and studies in single-cell systems are reported.

3363
McJones, R. W. and Beck, N. J. AUTOMOTIVE FUEL CELLS? NOT YET! Soc. Automotive Engrs. J., 70:31-33, figs., Feb. 1962.

Fundamental research will have to provide new discoveries before there is any chance for the fuel cell to become competitive with the reciprocating engine for vehicle powerplants.

3364
Micka, Karel. PRESENT STATE OF DEVELOPMENT OF FUEL CELLS. Chem. Listy 54:680-685, Jly. 1960.

In Czechoslovakian. A review.

3365
Moos, A.M. FUEL CELLS. Indus.Eng. Chem., 54:65-74, Jan.1962.

A hard look at fuel cells today. They are still military; not commerical. Early promise of two major processes is not yet realized.

3366
Morasca, Nicola. LE PILE THERMO-ELETTRICHE E LE PILE COMBUSTIBILI. (THERMOELECTRIC CELLS AND FUEL CELLS). Riv. Aero., 37:1251-1259, Aug. 1961.

In Italian. Discussion of thermoelectric cells and fuel cells, and of the possibilities they offer as sources of electric power. The operation of thermoelectric cells and of hydrogen-oxygen fuel cells is described, and possible applications to space and surface transport and to electric power stations are noted. (Intern. Aerospace Abs. 62-1429).

3367
REPORTS ARE RIFE ON BIG GERMAN DEVELOPMENTS IN FUEL CELLS. Chem. Wk., 88:51-52, Dec. 30, 1961.

It is reported in Germany that several leading companies have banded together to form a Working Group for Fuel Elements. Goal is to put to work the discoveries of Eduard Justi of the Brunswich Technical University. Justi presumably has found a way to use diesel oil as the fuel for a cell. Oil companies and others are said to be testing his method.

3368
Schmedel, S.R. ELECTRICAL FRONTIER OF THE FUEL CELL. Sci. Dig., 50:43, 45, Aug. 1961.

A condensed version of the article in the Wall Street Journal for Apr. 19, 1961, in which a general review is given of new generators capable of turning heat and chemical energy directly into electricity.

3369
SHORTCUT TO POWER. Chem. Wk., 76: 50-52, May 28, 1955.
Nontechnical article discusses implications of fuel cell development. Also outlines principal electrical, mechanical, and chemical features of the Bacon cell.

3370
STATE OF THE ART ACCESSORIES. Space Aero., 31:72-84, Mar. 1959.

Nontechnical article notes that hydrogen peroxide fuel cell is distinct possibility for unmanned space craft. Projects into the future to predict all space craft equipped with fuel cells.

3371
U.S. Army Research Office, OCRD, Washington 25, D.C.
FUEL CELLS, by B.R. Stein and E.M. Cohn. 76p., Dec. 1960. (Status Rept. 2).

This report covers recent literature, and government and private programs on fuel cell R&D.

3372
Voltz, S.E. and Kerr, D.L. WHAT PLACE IN SPACE FOR FUEL CELLS? Soc. Automotive Engrs. J., 70:48-49, figs., Mar. 1962.

Estimates performance and most likely fields of use for both primary and secondary fuel cells in space power applications.

3373
Yeager, Ernest. FUEL CELLS. Sci., 134: 1178-1186, figs., Oct. 20, 1961.

A general review article is presented with description of specific systems, and their applications.

2. Theory

3374
Petit, M.C. FUEL CELLS. Rev. Gen. Elec. 70:49-54, Jan. 1961.

In French. Reviews basic principles of electrochemical combustion phenomena such as the limitations imposed by the carnot cycle and direct production of electrical energy without involving it. Some operating conditions such as performance of gas electrodes and polarization are outlined. (Sci. Abs., 64B:5125, 1961).

3375
Salvi, G. and Fiumara, A. ELECTRICAL ENERGY FROM FUEL CELLS. Riv. Combust. 14:149-171, 1960.

In Italian. The thermodynamics and practical aspects of fuel cells operating at

low and high temperature are reviewed. Details are given of semicom. fuel cells. (Chem. Abs. 56:4505, Mar. 5, 1962).

3376
Watson, R. G. H. FUEL CELLS. Direct Curr., 1:30-34, 1953.

In this review article are found the thermodynamic principles of electrochemistry and a review of fuel cells with operating data for each.

3. Electrode Processes

3377
Alfred University, Alfred, N. Y. FUEL CELL ELECTRODE PROCESSES, Final Report, by G. J. Young and R. B. Rozelle. 12p., Sept. 1961. (Contract Nonr-1503(03)).

A study is reported of the fundamentals of fuel cell anode processes, particularly with the use of carbonaceous fuel gases. The cells studied were low temperature, low pressure cells with aqueous alkaline electrolytes.

3378
Strocchi, P. M. and Foraboschi, F. P. SOME THEORETICAL CONSIDERATIONS FOR FUEL OXIDATION-REDUCTION CELLS. Rend. Inst. Lombardo Sci. I, Sci. Mat. e Natur., 92A:43-50, 1957.

In Italian. Abs. in Chem. Abs. 49:12813, 1955.

3379
Brooklyn Polytechnic Institute, Brooklyn, N. Y. FUEL CELL MATERIALS, by H. P. Gregor et al. 2 issues, Nov. 30, 1960, Feb. 28, 1961. (Quart. Prog. Repts. 1, 2) (Contract DA36-039-sc-85384) (AD-255094, AD-262 528).

An improved cell for the measurement of the ohmic resistance of fuel cell electrdytes was designed. Work is being continued on improved homogeneous- and heterogeneous-type membranes; these will have catalyst incorporated into their faces. Cells for measuring the functional behavior of membranes in mixtures of organic liquid fuels and water were designed and are under construction.

3380
Calvin College, Grand Rapids, Mich. OXYGEN ADSORPTION BY THE SILVER ELECTRODE, by T. P. Dirkse and L. A. Vander Lugt. 15p., illus., Oct. 1, 1961. (Tech. Rept. 13) (AD-265 383).

A study was made of the coulombic efficiency of the silver electrode in KOH solutions. The coulomb input during anodization is greater than the coulomb output during cathodization plus the coulomb equivalent of the O evolved. This is interpreted as due to adsorption of O by the electrode during the process in which AgO is formed. Both constant current and constant voltage conditions were used.

3381
Gerischer, H. SEMICONDUCTOR ELECTRODE REACTIONS. In Advances in Electrochemistry and Electrochemical Engineering, p. 139-232, New York, Interscience, 1961.

Discussion is concentrated on semiconductor phenomena in the surface reactions at semiconductor electrodes.

A bibliography of 136 references is included.

3382
Holland, H. W. CARBON ELECTRODE FUEL CELL BATTERY. In Power Sources Conference. Proceedings, 15th, 1961, p. 26-29, Red Bank, N. J., PSC Publications Committe, 1961.

Basic information derived from research and development programs is translated into practical designs suitable for series connection of cells into batteries.

3383
Justi, Eduard and Winsel, A. W. THE DSK SYSTEM OF FUEL CELL ELECTRODES. Electrochem. Soc. J., 108:1073-1079, figs., Nov. 1961.

Different types of DSK electrodes such as economy electrodes used for the dissolved-fuel cell, and valve electrodes for the electrochemical storage of energy are described. They also act as electrolytic compressors with without moving parts and can control catalytic reactions automatically. DSK electrodes may be used for light storage batteries. Mo- and W-DSK electrodes offer the possibility of the electrochemical oxidation of CO. DSK electrodes belong to the most promising systems disclosed hitherto and are capable of further improvement.

3384
Lang, Maurice. RADIOISOTOPE-ACTIVATED FUEL-CELL ELECTRODES. Inst. Radio Engrs. Trans. MIL-6:58-62, illus., Jan. 1962.

It has been shown that a catalytic effect can be produced on oxygen fuel-cell electrodes by the incorporation of radioactive isotopes into the electrode structure. Experiments with β-emitters have resulted in low temperature and pressure silver electrodes capable of high current drains at favorable polarization values. Analysis of the data indicates support for the hypothesis that radiations exert a significant effect on diffusion control within the pores of the electrode.

3385
Rozelle, R. B. CATALYSIS OF FUEL CELL ELECTRODE REACTIONS. PhD thesis, New York State University, College of Ceramics, Alfred University, 95p., 1961.

This thesis concerns the investigation of the catalytic activity of the group VIII and Ib metals and certain alloys in fuel cell anode reactions. The gases, hydrogen, carbon monoxide, acetylene, ethylene, and propane are included in the investigation. Electrolytes employed were aqueous solutions of sodium hydroxide, potassium hydroxide and potassium carbonate.

The group VIII noble metals, when employed as catalysts at the hydrogen electrode, produce theoretical or near theoretical potentials for this electrode in aqueous sodium hydroxide electrolyte. The Ib metal catalysts, however, produce much lower potentials for this electrode. The theory is offered that the Ib metals do not lower the activation energy of chemisorption enough to establish a chemisorption equilibrium at the electrode surface and, hence, give lower than theoretical electrode potentials. The results for the other gas electrodes investigated employing the same catalysts follow a pattern similar to the results for the hydrogen electrode. Vacancies in the d-orbitals of the metal appear to be a requisite for a high catalytic activity in the gas electrodes investigated.

The hydrogen and oxygen electrodes were investigated under conditions of current drain. The variation of the potential-current density curves with electrolyte, electrode carbon, and temperature is discussed. (Dissertation Abs. 22:1842, Dec. 1961).

3386
Materials Research Laboratory, Waltham, Mass. SEMIANNUAL TECHNICAL SUMMARY REPORT ON ELECTROCHEMISTRY OF FUEL CELL ELECTRODES. 1/4 in. thick, Oct. 31, 1961. (Contract NObs-84770).

Progress is summarized for the first two phases of the program, viz. preparation and characteristics of sound electrode ingots; and electrolytic behavior of the materials in various media with an analysis of results.

3387
Monsanto Research Corp., Boston Laboratories, Everett, Mass. RESEARCH ON ORGANIC DEPOLARIZERS, July 1, - September 30, 1961. 51p., Sept. 30, 1961. (Contract DA36-039-sc-87336) (AD-269 594).

In attempting to set up a reproducible m-dinitrobenzene (m-DNB) half cell against which new organic depolarizers could be evaluated, several areas were defined that, if successfully exploited, could substantially increase the cathode voltage beyond any increase to be expected from new organic materials.

3388
Rusinko, Frank, Jr., Marek, R. W. and Parker, W. E. FUEL CELL MATERIALS, 2. CARBON ELECTRODES. In Power Sources Conference. Proceedings, 15th, 1961, p. 9-12, illus., Red Bank, N. J., PSC Publications Committee, 1961.

Initial phases are discussed of a research program, the objective of which is the preparation of carbon and/or graphite electrodes which will facilitate the development of fuel cell systems. Only that portion of the program is discussed for which fuel cell performance data are presently available.

3389
Salvi, G. R. and deBethune, A. J. THE TEMPERATURE COEFFICIENTS OF ELECTRODE POTENTIALS. II. THE SECOND ISOTHERMAL TEMPERATURE COEFFICIENT. Electrochem. Soc. J., 108:672-676, Jly. 1961.

Values of the second coefficient are tabulated for 58 standard electrodes, together with the first coefficients. Application of the data to fuel cells, and to emf-temperature relationships, is discussed.

3390
Speer Carbon Co., Research Laboratory, Niagara Falls, N.Y.
DEVELOPMENT OF ELECTRODE MATERIALS FOR FUEL CELLS, April 1 - September 30, 1961,. 2 issues, June, Sept. 1961. (Quart. and Final Repts.) (Repts. 4, 5) (Contract DA36-039-sc-85356) (AD-265 346, AD-270 819).

An experimental hydrogen-oxygen fuel cell was constructed and utilized to start the electrochemical evaluation of electrode materials prepared during the program. Some exceptional values were obtained.

Further studies on the wetproofing phase of electrode performance were carried out. Tentatively, it has been shown that the use of paraffin treatment is detrimental to electrode operation.

3391
Tyco, Inc., Waltham, Mass.
ELECTROCHEMISTRY OF FUEL CELL ELECTRODES. 3p., Jly. 10, 1961. (Quart. Letter Rept. 1) (Contract NObs 84770) (AD-265 508).

Objective of the program is the correlation of the catalytic activity of electrode surfaces (for electro transfer) with the electronic properties, and, in turn, the composition and structure of the electrode compounds, i.e. elements with incompletely occupied d-orbitals.

3392
Yardney Electric Corp. ISOTOPE-TREATED ELECTRODES ARE IN NEW FUEL CELL. Eng. & Mining J., 162:50, Sept. 1961.

A fuel cell using electrodes treated with radioactive isotopes may lead to a commercial break-through in fuel-cell research and development. The new method has produced an impressive decrease in polarization as compared with untreated electrodes. Tests show that the use of radioactive isotopes as catalyst for an oxygen electrode made of sintered, porous silver in low-temperature alkaline electrolyte permits a current density of 150 mA/cm^2 to be sustained for extended time periods at polarizations of 0.2 to 0.3 V. The voltage does not change with time. (Fuel Abs. & Current Titles 2: 8370, 1961).

3393
Cohn, G. FUEL CELL MATERIALS. 3. CATALYSTS. In Power Sources Conference. Proceedings, 15th, 1961, p. 12-16, figs.. Red Bank, N.J., PSC Publications Committee, 1961.

The work discussed demonstrates the feasibility of efficient cathodic conversion of oxygen in acid media at ordinary temperatures employing platinum as catalyst. For anodic oxidation of methanol- as well as of other organic fuels - under these conditions it is necessary to find catalysts less subject to polarization under load than platinum.

3394
BACON TYPE OF PRIMARY FUEL CELL.. Aviat. Wk., 7 Space Tech. 75:19, Nov. 27, 1961.

Listed in section "Industry Observer," "Bacon type of primary fuel cell under consideration by NASA to furnish Apollo power requirements is expected to supply an average of two kilowatts during a 14-day mission for a three-man crew, or about 665 watts per man. This is more than two and a half times that projected by Air Force about four years ago for missions spanning Man-in-Space Soonest, Man-in-Space-Sophisticated, and lunar reconnaissance. The Bacon type of cell, using hydrogen and oxygen, is being developed by Pratt & Whitney Division of United Aircraft Corp." Entire item quoted.

4. Primary

3395
Blackmer, R.H. and Phillips, G.A. ION-EXCHANGE MEMBRANE FUEL CELL COMING FOR SPACE VEHICLES. Soc. Automotive Engrs. J., 30:82-86, figs., Jan. 1962.

An experimental ion-exchange membrane fuel cell is being developed for use in a wide range of space vehicles. A 9-cell demonstration battery has been constructed using conductively cooled cells. (Curr. Contents 2, Jan. 16, 1962).

3396
Chapman, L. E. and Oster, E. A. ION-EXCHANGE FUEL CELL BATTERY. In Power Sources Conference. Proceedings, 15th, 1961, p. 21-26, Red Bank, N. J., PSC Publications Committee, 1961.

The feasibility of a small, portable, air-breathing fuel cell power source with an integral hydrogen generation system has been demonstrated as indicated by a report of General Electric's 200 watt development program. This program has shown that the ion exchange membrane fuel cell has the potential for long life air-breathing operation with satisfactory operation at ambient temperatures from 32° to 120°F and relative humidity from 15 to 100 percent.

3397
CHEMICAL CURRENT. Indus. Eng. Chem. 46:11-A, Oct. 1954.

Nontechnical article describes work in progress in Great Britain. The Bacon cell is described, using porous nickel diffusion electrodes 4mm thick with 30 micron pores on gas side and thin layer of much small pores on the liquid side.

a. Hydrogen-Oxygen

3398
Danbski, J. NEW ACHIEVEMENTS IN ELECTRIC CELLS. (Chemik(Gliwice) 11:61-62, 1958.

In Polish. Description of cell in which gaseous H and O are burned and give electric energy; electrolyte is KOH and electrodes of Ni (or preferably of C); in case of C electrodes, only room temperature and nearly atmospheric pressure of gases is required. Efficiency of changing chemical into electrical energy is 65-80%. Cell adaptable to military purposes, such as supplying current to small field radar stations. (Fuel Cell Bibl. Mond Nickel Co., 1960).

3399
DIRECT CONVERSION WITH FUEL CELLS? Nucleonics 16:110, Jly. 1958.

Discusses briefly the National Carbon Company's hydrogen/oxygen fuel cell. The cell is said to have an efficiency of about 70% and an essentially infinite life. The article also points out the use of fuel cells to utilize dissociated oxygen from various reactors.

3400
DIRECT CONVERSION OF CHEMICAL ENERGY INTO ELECTRICITY IS NOW POSSIBLE. Chem. Eng. Prog., 53:82+ (Suppl.), Sept. 1957.

This nontechnical article discusses National Carbon's hydrogen/oxygen cell in a qualitative manner. Outlines chemistry, mentions catalyst in the electrode (not specified), and discusses high cost of hydrogen.

3401
ELECTRICITY FROM GASES. Mech. Eng., 79:1050-1051, 1957.

Nontechnical article describes general nature of National Carbon's hydrogen/oxygen fuel cell. It is stated that normal operating temperature is 120°F to 140°F. Cell will deliver approximately one kilowatt from one cubic foot of cell.

3402
FUEL CELL OBTAINS HIGH EFFICIENCY. Electron., 34:72, Nov. 24, 1961.

A wafer-type fuel cell, developed by the Armour Research Foundation of Illinois Institute of Technology, and which can supply electrical power in the high-temperature and radiation environment of outer space, is described briefly. Using hydrogen and oxygen for fuel, the cell is composed of an inorganic ion-exchanging membrane which operates at higher temperatures than the organic types now in use. (Fuel Abs. & Curr. Titles 3:1243, Feb. 1962).

3403
FUEL CELL PASSES SPACE TEST, Chem. & Eng. News 40:62, Jan. 15, 1962.

A modified hydrogen-oxygen fuel cell has passed the gravity-independence phase of simulated space flight tests. The primary fuel cell is being tested for use in extended orbital flights under Project HOPE (Hydrogen oxygen primary extraterrestrial fuel cell program).

3404
FUEL CELL SILENTLY CONVERTS GASES TO BIG ELECTRIC POWER. Mach. Design, 29:6-7, Oct. 3, 1957.

Non-technical article discusses claims and

service of National Carbon hydrogen/oxygen fuel cell. Mentions cell usage in Silent Sentry radar.

3405
FUEL CELL STUDIED AT NEW LABORATORIES. Elec. Eng. no. 75, p. 1143, 1956.

Nontechnical article discussed qualitatively the proposed program of National Carbon's Laboratory at Parma, Ohio, on the hydrogen/oxygen fuel cell.

3406
FUEL CELL TURNS GASES INTO ELECTRICITY. Indus. Eng. Chem. 49:32A, 34A, Nov. 1957.

Nontechnical article discusses fuel cell developed by Research Laboratory of National Carbon Division of Union Carbide. Uses hydrogen/oxygen with KOH electrolyte. The cell uses porous carbon electrodes. Mentions lithium atoms used in crystal lattice of nickel oxide used in Bacon cell to create semiconductor and prevent corrosion of oxygen electrode.

National Carbon's cell operates at room ambient conditions. Bacon is working to complete a 10 kilowatt cell by August 1959. National Carbon's cell has been operated eight hours a day, five days a week for one year with no apparent deterioration. Present designs call for specially catalyzed, porous carbon electrodes in a sealed cell with KOH electrolyte for National Carbon cell. No numerical data is presented.

3407
FUEL CELLS FOR PORTABLE POWER. Prod. Eng., 26:201, June 1955.

Nontechnical article describes plans of British Electrical and Allied Industries Research Association to make a 2-3 kilowatt prototype Bacon cell with guaranteed life of 1000 hours. The laboratory cell designed by Bacon is a short cylinder of 5 in. I. D. Inside the two halves of the cylinder and centered between them are two porous nickel electrodes, 5/32 in. thick and 1/16 in. apart. A 27% KOH aqueous electrolyte circulates between electrodes by thermal syphon. Cell operates at 140°C to 240°C at 600 to 800 psi. A positive pressure of 1.5 pse is maintained in the gas chambers to prevent electrolyte from entering the chambers.

3408
GAS FED ELECTRIC CELL. Bus. Wk., p. 81-82, Sept. 21, 1957.

This is a nontechnical article containing a brief description of National Carbon's hydrogen/oxygen cell. It mentions 60% to 80% electrical conversion efficiency with the rest of the conversion energy going into heat.

3409
GASES PRODUCE POWER IN NEW ELECTRICAL GENERATOR. Sci. News Ltr. 72:277, 1957.

A very brief item mentions a hydrogen-oxygen fuel cell used to power the Army's Silent sentry radar.

3410
GENERATION OF ELECTRICITY IN FUEL CELLS. Mech. World 35:18-20, Jan. 1955.

Review of Bacon cell, high-temperature indirect cells (Gorin, etc.), high-temperature direct cell (Justi); future developments; historical survey (Mond and Langer, etc.).

3411
IMPROVED FUEL CELL MAKES FRESH BID AS POWER PRODUCER. Power 102:87, Jly. 1958.

Nontechnical article shows schematic of National Carbon's hydrogen/oxygen cell. Mentions that cell should operate at 65% to 80% efficiency at 120°F to 140°F and about atmospheric pressure. Should deliver one kilowatt per cubic foot at one volt.

3412
INORGANIC-MEMBRANE FUEL CELL GENERATES HIGH POWER. Mach. Design 33:14, illus., Dec. 21, 1961.

Fuel cell the size of a quarter operates at 90% efficiency, generates slightly less than 1 v, and produces a current density of 100 amp per sq ft. Organic-membrane cells produce about 35 amp per sq ft.

3413
INORGANIC MEMBRANE WORKS IN FUEL CELLS. Chem. & Eng. News 39:40, Oct. 16, 1961.

The membrane is composed of mixed

powdered polymerised $ZrO(H_2PO_4)2$ and Teflon, compressed into a disc 1 inch diameter by 0.03 inch thick; each side has a layer of the zirconium polymer mixed with platinum black, then a layer of platinum black and than a covering platinum screen. The membrane is designed to work in a hydrogen-oxygen or hydrogen-air fuel cell at temperatures up to 100°C, and efficiencies up to 3 amps per square foot at 0.6 volt have been attained.

3414
Ionics, Inc., Cambridge, Mass.
STUDY OF ION EXCHANGE MEMBRANE FUEL CELL COMPONENTS, Final Report, by R.M. Lurie, R.J. Shuman, and H.I. Viklund. 19p., illus., Oct. 30, 1961. (Contract DA44-009-eng-4554) (AD-266 036).

The results are presented of work on the development of improved hydrogen-oxygen ion exchange membrane fuel cells. Studies included catalysts electrode structure, membrane composition and thickness, cell design, and structure. This work demonstrated the advantages of the concept of a dual membrane cell. Major features include safety, ease of humidification in air-breathing cells, ease of cooling and water removal in oxygen cells, and high allowable current densities (lower cell weight). Over 6 weeks of continuous operation at 16 amps/sq.ft. at room temperature and atmospheric pressure with no change in performance indicates the advance in the state of the art of membrane fuel cells that was obtained.

3415
Klass, P.J. GASES PROVIDE SILENT POWER SOURCE. Aviat. Wk. 67:69, 71, 73, 75, Sept. 23, 1957.

A new fuel cell is described which directly converts hydrogen and oxygen into electricity without combustion or moving parts, and which operates at moderately low temperatures and at atmospheric pressure, unlike previous fuel cells.

3416
Kordesch, K. and Marko, A. UEBER NEUARTIGE KOLE-SAUERSTOFF-ELEKTRODEN. (CONCERNING A NEW CARBON/OXYGEN ELECTRODE). Osterr. Chem.-Z., 52:125-131, 1951.

In German. Describes a hydrogen/oxygen cell. Mention is also made of the use of formaldehyde as a fuel.

3417
MORE COLD COMBUSTION ADVANCES AIRED. Chem. Eng., 63:110-112, Feb. 1956.

This is a non-technical article discussing a cell, under development in West Germany, very similar to the Bacon cell but operating at 22 psi and 212°F. No performance data is presented and no names are mentioned.

3418
SIZABLE POWER OUTPUT FROM FUEL CELLS-SOON? Power 99:97, 1955.

Non-technical article on Bacon cell designed by F.T. Bacon and T.M. Fry. Cell is 5 in. in diam., has 5/32 in. porous nickel electrodes with 1/16 in. separation. 27% KOH solution electrolyte is used between electrodes. Cell operates at 284°F at 600 to 800 psi. Maximum theoretical operating cell voltage is 1.2 volt; 90% of this voltage is attained. Efficiency drops to 50% on severe overloads. Running cell at 392°F, a current of 0.2 amp/cm^2 at 0.8 volts was observed at 65% efficiency. This rating was most conducive to long life.

3419
U.S. Air Force, Wright Air Development Center, Wright-Patterson Air Force Base, Ohio.
HYDROGEN-OXYGEN FUEL ELECTROLYTIC BATTERY CONTAINER STUDY, by J.R. DeHann and Marshall Piccone. n.p., Oct. 1958. (AD-203-521).

Various methods of storing hydrogen and oxygen to support an electrochemical reaction fuel cell have been studied. Various insulation methods were studied and their applicability to specific missions are discussed.

3420
Universal Winding Co., Jamaica, N.Y.
CONTINUOUS FEED FUEL CELL SYSTEMS, by L.R. Alexander, A.M. Moos, et al. 100p., Sept. 1957. (WADC TR 57-605) (Contract AF33(600)-34709) (AD-142 016).

A design study is presented of the factors involved in adapting continuous feed fuel cell systems to use as power supplies

aboard air vehicles. The hydrogen-oxygen feed fuel cell system consisting of three sub-systems (electrical generator, fuel storage system, and controls) is the basis of the study.

b. Carbonaceous

3421
Bauer, E. and Preis, H. ÜBER BRENNSTOFF-KETTEN MIT FESTLEITERN. (CONCERNING A FUEL CELL WITH A SOLID ELECTROLYTE). Z. Elektrochem., 43: 727-732, 1937.

In German. This technical article presents a study of a carbon/air fuel cell using a fused electrolyte of CeO_2, WO_3, and Ball Clay. The cell operates at 100°C, 1 atmosphere pressure, and delivers 3.52 a/ft^2 at 0.7 v. The cell shows no over-voltage.

3422
California Research Corp., Richmond, Va. INVESTIGATIVE STUDY RELATING TO FUEL CELLS. 2 issues, June 26, Oct. 27, 1961. (Quart. Prog. Repts. 4, 5) (Contract DA49-186-502-ORD-929) (AD-260 347, AD-267 073).

Product studies with methanol in an acid electrolyte fuel cell were continued and studies of hydrocarbon oxidations at fuel cell anodes were extended.

3423
Caputo, C. SULLA TRASFORMAZIONS DIRETTO DELL ENERGIA CHEMICA DEL CARBONE IN ENERGIA ELETTRICA. (ON THE DIRECT TRANSFORMATION OF THE CHEMICAL ENERGY OF COAL INTO ELECTRICAL ENERGY). Ingegnere no. 29, p. 763-775, 1955.

In Italian. This article discusses primary cells with solid or gaseous electrodes. Bischoff's cell at 700°C, using pulverized coal for fuel, delivered 0.5 milliamp/cm^2 at 0.6 volts. Bacon's cell (using 27% KOH electrolyte, porous nickel electrodes, and hydrogen fuel) delivered 650 milliamps/cm^2 at 0.62 volts at 200°C. Davtyan's cell used solid electrolyte of Na_2CO_3, monazite, tungsten trioxide, and sodium glass. A table of references to articles concerned with carbon direct fuel cells is given. This review article is a technical discussion.

3424
Daniel-Bek, V.S. et al. THE USE OF HYDROCARBON FUEL IN CELLS WITH SOLID ELECTROLYTES. Zhurn. Priklad. Khim. 32:649-655, 1959.

In Russian. Transl. RJ-1892 available from Associated Technical Services, East Orange, N.J.,

Data show that solid electrolyte cells can operate using gasoline and other fuels. Operating temperature 700-750°C, c.d. 1.0-1.5 amp/d^2, 0.5-0.7 v.

3425
Davtyan, O.K. GAS CELL WITH A SOLID ELECTROLYTE. Akad. Nauk SSSR. Otdel. Tekh. Nauk. Izvest. no. 2, p. 215-218, 1946.

In Russian. Transl. RJ-464 available from Associated Technical Services, East Orange, N.J.

Design and performance of a fuel cell employing air and CO electrodes separated by a solid electrolyte are described. Cell operates at 500-1000°C and generates electricity with 80% efficiency.

3426
Davtyan, O.K. A STUDY OF SOLID ELECTROLYTES FOR GAS CELLS. Akad. Nauk. SSSR. Otdel. Tekh. Nauk. Izvest. no. 1, p. 107-114, 1946.

In Russian. Transl. no. CCT-518TT available from Consultants Custom Translations, Inc., New York, also from Associated Technical Services, Inc., East Orange, N.J.

The study included mixtures of Na_2CO_3, monazite, WO_3, CaO, quartz, clay & soda glass. Many combinations were found suitable for service at 650-800°C. Electrical conductivity data is reported.

3427
Degobert, P. FUEL CELLS WITH MOLTEN ELECTROLYTES. Rev. Inst. Franc. Petrole 16:747-771, June 1961.

In French. After a brief recapitulation of the characteristics of a fuel cell, the difficulties encountered in the use of hydrocarbons, and the advantages of the high-temperature cell in such cases, are indicated. The problems associated with

the chemical nature and conductivity of molten electrolytes are then described, in order to enable the most suitable selection of electrolytes to be made for the cells under discussion. The question of electrodes is next considered, with particular emphasis on the respective physical characteristics of electrode and electrolyte, electrode and gases or fuel. Finally, the latest developments in the field of cells with molten electrolyte are discussed. (Fuel Abs. & Current Titles 2:6785, 1961).

3428
Engelhard Industries, Inc., Newark, N. J. FUEL CELL CATALYSTS. 2 issues, June 30, Sept. 30, 1961. (Quart. Repts. 4, 5) (Contract DA36-039-sc-85043).

A research program is active on electrode catalysts for fuel cells employing liquid organic fuels. Complete oxidation of the fuel to carbon dioxide and water is required under expulsion of these products from the fuel cell. The electrolyte of the cell, therefore, must be preferably acidic. The work of the reports period showed that higher concentration of methanol or its oxidation products inhibit all cathode catalysts. Platinum modified with gold is most resistant to this type of inhibition. For anodic methanol oxidation no better catalyst than platinum has so far emerged, which is, however, still inadequate due to high polarization under load.

3429
FUEL CELL GENERATES ELECTRICITY. Sci. News Ltr. 74:373, Dec. 13, 1958.

Everett Gorin and Howard Recht of Pittsburgh Consolidation Coal Company, of Library, Pa., describe work at the American Socity of Mechanical Engineers meeting in New York. The gaseous fuel cell work was sponsored by the U.S. Army Signal Corps.

3430
Gaylor, P. J. FUEL CELL CONVERTS PRODUCER GAS DIRECTLY TO ELECTRICAL ENERGY. Petrol. Process no. 7, p. 363, 365, 1952.

Nontechnical report discusses the fuel cell developed by Pittsburgh Consolidation Coal Company, for which an overall efficiency of 60% is claimed. Air is fed into the anode chamber of iron magnetite at high temperatue, gas is fed through an iron-iron oxide cathode. The device uses solid glass electrolyte. Flow diagrams are included.

3431
General Electric Co., West Lynn, Mass. RESEARCH ON LOW TEMPERATURE FUEL CELL SYSTEMS. 4 issues, May, Aug., Sept., Nov. 1961. (Prog. Repts. 16, 17, 18, 19) (Contract DA44-009-eng-3771) (AD-264 309, AD-265763, AD-268 235, AD-269 227).

Fuel electrode studies resulted in the following: Development of two electrode structures for carrying out fuel and electrocatalyst investigations in matrix-type fuel cells, and cell structures including one with reference electrodes; A survey of chemical elements for electrocatalytic activity with H, hydrocarbons, and other fuels, C base electrocatalysts for activity with H, hydrocarbons, and O, and a number of mechanical mixtures and compounds and a few alloys for electrocatalytic activity in fuel cells; Identification of Pt as the most active simple catalyst for anodic oxidation of hydrocarbons in fuel cells; Discovery that saturated hydrocarbons are more rapidly oxidized in acidic electrolyte cells as compared with basic electrolyte cells and that with olefins the electrolyte effect is smaller and in favor of the basic electrolyte; and Identification of strong effects of electrolyte upon adsorption rates of hydrocarbon fuels which correlates with the observations of the preceding item.

3432
Gregor, H. P. FUEL CELL MATERIALS. 1. ION-EXCHANGE MEMBRANES. In Power Sources Conference, Proceedings, 15th, 1961, p. 4-9, illus., Red Bank, N.J., PSC Publications Committee, 1961.

This contribution describes ion-exchange membrances, lists their principal preparative procedures and discusses their function in gaseous and liquid fuel cells.

3433
Netherlands. Central Technical Institute, TNO, The Hague. HIGH TEMPERATURE GALVANIC FUEL CELLS, by G. H. J. Boers and M. Schenke. 4 issues, 1960-1961. (Quart. Repts. and Final) (Quart. Rept. 1, 2, 3 and Final) (Contract DA-91-591-EUC-1398).

The work described involves experimental and some theoretical research. It deals, first, with investigations on electrolyte moulding techniques and secondly, with experiments on complete fuel cells.

3434
POWER THROUGH HEAT. Electron. World, 145:24, 1952.

Nontechnical article discusses Pittsburgh Consolidated fuel cell. Dr. Everett Gorin of Pittsburgh Consolidation Coal Co. has patent. Efficiences to 75% are claimed. The biggest problem to overcome is operating life. One cell produced approximately 0.75 kilowatts.

5. Regenerative

3435
Aerospace Corp., El Segundo, Calif. FUEL CELL RESEARCH PROGRAM. CHLORINE-PHOSPHORUS TRICHLORIDE FUEL CELL INVESTIGATIONS. by F. Hess and L. Schieler. 4p., June 30, 1961. (Semiannual Tech. Rept.) (Rept. TDR-594(1201-01)TR-1) (Contract AF04(647)594) (AD-266 441).

A description is given of a fuel cell research program for space power applications. The primary objective of the program is the investigation of a regenerable fuel cell utilizing the thermal or photolytic dissociation of phosphorus pentachloride to phosphorus trichloride and chlorine as a source of chemical energy. Data reveal that thermal dissociation is feasible but photolysis techniques will need further study. Theoretical background is given for electrode reactions of the phosphorus trichloride -chlorine fuel cell and the technical progress made in this investigation during the last six months is summarized.

3436
Agruss, B., Hietbrink, E. H. and Henderson, R. E. REGENERATIVE FUEL CELLS FOR ENERGY STORAGE. In Power Sources Conference. Proceedings, 15th, 1961, p. 38-43, figs., Red Bank, N. J., PSC Publications Committee, 1961.

The study indicates basic problems which must be overcome before giving serious consideration to the fuel cell as a workhorse space electrical storage system. Improvement must be achieved in electrochemical characteristics, reduction of polarization losses, providing low resistance reversible cells, and in simplifying the storage system.

3437
Armour Research Foundation, Chicago, Ill. CHEMICAL CONVERSION OF WASTE HEAT TO ELECTRICAL ENERGY, June 1960-October 1961. 5 issues, Oct. 1960, Jan., Apr. Jly., Oct. 1961. (Quart. Repts. 1-5) (Contract NOw 60-0760-c).

This project, which involves the conversion of heat to electrical energy, has as its objective the optimization of thermally regenerative chemical systems for three different temperature ranges. Principal phases for investigation are: (1) selection of promising systems with the Univac 1105 computer; (2) kinetics of regeneration reactions; (3) electrolyte and galvanic cell studies.

3438
Bone, J. S. and others. ION-EXCHANGE REGENERATIVE FUEL CELLS. In Power Sources Conference. Proceedings, 15th, 1961, p. 47-50, figs., Red Bank, N. J., PSC Publications Committee, 1961.

A new cell structure is described which has attractive characteristics for regenerative operation. Because of the absense of a free-flowing fluid electrolyte the cell appears ideally suited for use in a gravity-free environment. The cell has no moving parts and good intrinsic stability. It therefore holds forth the promise of providing a sorely needed, long-lived energy storage device for use in space technology.

3439
Electro-Optical Systems, Inc., Pasadena, Calif. CHEMICAL REACTIONS TO CONVERT SOLAR ENERGY INTO POWER SOURCES, by J. J. Rowlette. 44p., illus., Sept. 1961. (Rept. ARL-60) (Contract AF33(616)6546) (AD-269 508).

Photochemical synthesis of H_2O_2 and the combined thermal-photochemical decomposition were studied for the ultimate possibility of using sunlight for regenerative electrolytic cells, or for the purpose of making H_2O_2 for other high energy applications. Theoretical analysis of the photolysis and thermal decomposition of SO_3 strongly indicated that a combination of a photochemical and thermal decomposition would not yield a decomposi-

tion greater than the 2 processes used separately. H_2O_2 synthesis was accomplished in both liquid and gaseous states using cadmium telluride and zinc oxide as photocatalyst. Without organic additives in the liquid phase, neither catalyst shows any promise. In the presence of the additives, the reactions are always exothermic and consequently of no value for energy conversion.

3440
Electro-Optical Systems, Inc., Pasadena, Calif. EVALUATION OF REGENERATIVE FUEL CELL, September 21, 1960 - September 8, 1961. 2 issues, Mar. 31, Oct. 8, 1961. (Eng. Rept.) (Repts. 1584-IR-1 and 2) (Contract NAS7-7).

Experimental techniques are described; and results and accomplishments are discussed. Objective of the program has been the evaluation of the effects of the important and controllable parameters on the performance characteristics of a regenerative hydrogen-oxygen fuel cell.

3441
Electro-Optical Systems, Inc., Pasadena, Calif. INVESTIGATION OF NEW SOLAR REGENERATIVE FUEL CELL SYSTEMS, by J. J. Rowlette. 2 issues, Jan., Jly. 1961. (Repts. 1720-2Q-1 and 2) (Contract DA 36-039-sc-87425).

Solar energy conversion by fuel cells regenerated either photochemically or thermally have been evaluated, and the results are discussed.

3442
Henderson, R. E. NUCLEAR FUEL CELLS. In American Power Conference. Proceedings, v. 23, p. 44-48, Chicago, Ill., Illinois Institute of Technology, 1961.

Regenerative fuel cells are suggested as a means of utilizing nuclear energy. Several developments are reviewed. A table lists inorganic compounds usable in thermal regeneration.

3443
Lee, J. M. and Hamdlewich, R. M. REGENERATIVE H_2O_2 FUEL CELL SYSTEM. In Power Sources Conference. Proceedings, 15th, 1961, p. 43-46, figs., Red Bank, N. J., PSC Publications Committee, 1961.

Basic components are described for a zero gravity regenerative energy storage system. They are a Bacon type oxygen-hydrogen fuel cell, a high-pressure-high temperature electrolysis cell and a centrifugal gas-liquid separator.

3444
Lockheed Aircraft Corp., Missiles and Space Division, Sunnyvale, Calif. SOLAR REGENERATIVE CHEMICAL SYSTEM, January 1 - December 31, 1961, by H. P. Silverman. 2 issues, June, Dec. 1961. (Repts. 4, 5) (Contract DA 36-039-sc-85245) (AD 268 401; AD-274 481).

A study of photochemical and thermochemical approaches to convert solar to electrical energy is reported. A regenerative-type fuel cell based on thermal dissociation of cadmium iodide or stannous iodide is shown to be unfeasible. Experiments are described and theory presented for thermocell and double thermogalvanic cell thermal regenerative systems.

3445
Ludwig, F. A., McClelland, D. H. and Frank, H. A. DESIGN PARAMETERS FOR REGENERATIVE CELLS. In Power Sources Conference. Proceedings, 15th, 1961, p. 33-37, figs., Red Bank, N. J., PSC Publications Committee, 1961.

Important comparison criteria are discussed, such as efficiency, weight, and reliability.

3446
MSA Research Corp., Callery, Pa. STUDY OF ENERGY CONVERSION DEVICES, Final Report, by T. A. Ciarlariello, J. B. McDonough and R. E. Shearer. 69p., Sept. 14, 1961. (Rept. 7; MSAR 61-99) (Contract DA 36-039-sc-78955) (AD-270 212).

During this contract, regenerative cells were built and tested for various periods of time. The major difficulties noted were the plugging of the circulating salt lines, the low dissociation pressure of LiH in dilute solutions, and an electric cell-shorting effect arising after long duration.

Various molten salt electrolytes were tested. Low melting point eutectic salts containing Na, Rb, Cs, K, and Li were found. Fluorides, bromides, and chlorides were found to be the best electrolytes. Borohydrides and iodides were not satisfactory.

3447
Pennsylvania State University. Mineral Industries Experiment Station, University Park, Pa.
REDOX FUEL CELLS, by L.G. Austin. 4p., Sept.1, 1961. (Quart. Prog. Rept. 6) (Contract DA 49(186)502-ORD-917) (AD-266 103).

An analytical procedure was developed for determining Sn(++), but it has not been possible to determine Sn(4+) ion in the presence of Sn(++), or to quantitatively reduce SN(4+) to Sn(++) by means of the Jones reductor. At temperatures below the normal boiling point, no reduction of Sn(4+) to Sn(++) is obtained with HCHO as the reducing agent, in concentrated HCl solutions. At 200 C, a high pressure build-up occurs in the reaction tubes; on breaking the tubes, the pressure release is so violent that it is difficult to collect the sample. Although this may be invalidating the results, no reduction of Sn(4+) to Sn(++) was observed.

3448
Posner, A.M. REDOX FUEL CELL. Fuel 34:330-338, 1955.

This article presents a detailed description of the Redox fuel cell. Some details of construction are presented along with the considerations involved in design. Operating data for the stannous chloride/bromine cell are presented.

3449
Shearer, R.E. and Werner, R.C. THERMALLY REGENERATIVE IONIC HYDRIDE GALVANIC CELL. Electrochem. Soc. J., 105:693, 1958.

This brief communication reports the investigation at MSA Research Corporation of alkali and alkaline earth and hydrogen fuel cells. The product of electrochemical reaction is thermally decomposed to the fuel and oxidant. An open circuit voltage of 0.6 v was obtained with chloride-fluoride eutectic at 550°C. Reports 150 c/ft^2 under maximum power, predicts 90 w/ft^3. Quotes Carnot cycle efficiency of 35%.

3450
Silverman, H., Momyer, W.R. and Eisenberg, M. PHOTOCHEMICAL REGENERATIVE FUEL CELL. In Power Sources Conference, Proceedings, 15th, 1961, p.53-58, Red Bank, N.J., PSC Publications Committee 1961.

Properties of the proflavine-ascorbic acid system and its performance in a photo-regenerative power device, are described in detail.

3451
Voltz, S.E. and Read, M.D. REGENERATIVE HYDROGEN-OXYGEN FUEL CELL. Inst. Radio Engrs. Trans. MIL-6:63-67, illus., Jan.1962.

This paper discusses some of the basic principles concerned with this type of fuel cell and presents typical data to illustrate the present state of development.

3452
Sundstrand Aviation-Denver. Engineering and Testing Laboratories, Pacoima, Calif.
A NITROSYL CHLORIDE SOLAR REGENERATIVE FUEL CELL SYSTEM, by W.R. McKee and E. Findl. 122p., Jly.1961. (WADD TR 60-821, Pt.II) (Contract AF 33 (616)-6585) (AD-267 060).

Discussed herein are data relating to the model fabrication, preliminary system tests, separation of regenerated fuels and the development of the nitric oxide-chlorine fuel cell.

6. Biochemical

3453
BIOCHEMICAL FUEL CELL CONVERTS HEAT TO ELECTRICITY. Sci. Dig., 50: 89, Sept.1961.

Brief reference is made to a report in Business Week of two laboratory projects connected with a so-called biochemical fuel cell - that of Joseph Kaye & Co. in Cambridge, Mass. and that of Dr. F.D. Sisler of the Interior Dept.

3454
BIOCHEMICAL FUEL CELLS. Aerospace Manag., 5:54, Apr.1962.

"Biological catalysts and food components such as sugar and protein have been used to generate minute electrical currents. The energy conversion research is being carried out by Electro-Optical Systems and Sonotones. Present laboratory curiosities are held to be potential sources of electricity during space flight using human waste as fuel." Entire item quoted.

3455
BIO-POWER DEVICES SHOW PROMISE AS POWER SOURCES. Elec. Eng. 80:987, Dec. 1961.

A brief article refers to new(life-energy) sources of electric energy which have, so far, been developed in three different models. The first is a bio-battery that uses natural minerals and organic matter contained in ordinary sea water. Billions of bacteria consume these nutrients, producing an electric potential between the poles of the battery. The second type is the bio-fuel cell using organic matter and air. The third is the bio-solar cell that makes use of photosynthetic organisms that convert solar energy directly into electricity at efficiency levels that may ultimately be far above those achieved by any other known device.

3456
ELECTRICAL POWER FROM BACTERIA. Aviat. Wk. & Space Tech., 75:63, Oct. 23, 1961.

"Batteries supplying reasonable levels of power by converting life energy of bacteria into electrical power are being developed by Magna Products, Inc., Anaheim, Calif. In one concept bacteria with an appetite for specific minerals are placed together with them in a container of sea water. As the bacteria eat the minerals, the latter's electrical state changes. This change of state, occurring during metabolic processes, is then the source of current since it creates an electron movement. In another type of battery, somewhat akin to the photovoltaic process used in conventional solar cells, bacteria of certain type release energy in response to certain wavelengths in the solar spectrum." Entire item quoted.

3457
RESEARCH ON A "BIOLOGICAL FUEL CELL". Chem. Wk. 90:70, Mar. 10, 1962.

Brief mention is made of a demonstration of a radio transmitter powered by bacteriological action. Frederick D. Sisler showed the transmitter and the power generation source: bacteria feeding on sugar in a 7 in. test tube that also contained sea water.

Mention is also made of a company having reported production of small electrical currents utilizing biological catalysts and ordinary foods (e.g., sugar and protein).

3458
Sisler, F. D. ELECTRICAL ENERGY FROM BIO-CHEMICAL FUEL CELLS. New Scientist 12:110-111, figs., Oct. 12, 1961.

The biochemical fuel cell described was conceived through observation of electrochemical processes in marine sediments. The essential components required to demonstrate the direct conversion of chemical energy to electrical energy through the agency of sulphate-reducing bacteria are a pair of test tubes, an electrolyte bridge of potassium chloride in agar, platinum electrodes, sea water medium, and a culture of Desulfovibrio; together with a voltmeter to measure the electric charge released. The use of a biochemical fuel cell for production of electrical energy may have limited applications for specialized purposes. The chief advantage lies in the utilization of a great variety of organic materials which may otherwise be of little or no commercial value.

B. Primary Batteries

3459
Barak, M. BATTERY RESEARCH AND DEVELOPMENT--THE INSATIABLE DEMAND FOR POWER. Radio & Electron. Comp., 2:745-749, illus., Oct. 1961.

A survey is made of research and development now being carried out on batteries at the Central Laboratories of the Chloride Electrical Storage Company. The fundamental principles of battery manufacture are discussed together with the problems of improving battery efficiency, life, and the reduction of weight.

3460
Bartosh, S. J. and Pawlak, J. C. ORGANIC PRIMARY CELLS. U.S. Patent 3,025,336 (to U.S. Army), Feb. 14, 1961.

A primary cell comprising a magnesium anode in combination with a cathodic material composed of meta dinitrobenzene and barium chromate, the cathodic material being mixed with carbon black in an electrolyte of magnesium, perchlorate solution containing lithium chromate, and where said carbon black is characterized

by a fine particle size of about 500 angstroms, a chain structure of ellipsoidal to round particles, a large surface covering area on the order of 800 square meters per gram and a high electrolyte absorption such that 5 grams of the carbon black when shaken with standard aqueous electrolyte requires at least 19 milliliters of the electrolyte to agglomerate the carbon black into a single ball. (U.S. Pat. Off. Off. Gaz. 776:542, Mar. 13, 1962).

3461
Brenet, J., Thirsk, H.R. and Tragardh, A.U. MAJOR SCIENTIFIC PROBLEMS IN PRIMARY AND SECONDARY CELLS. In International Committee of Electrochemistry, Thermodynamics and Kinetics. Proceedings, 9th, Paris, 1959, p. 395-419, London, Butterworths Scientific Publications, 1959.

A review of problems concerning the primary cells of the Leclanche type, the Pb acid accumulators, and the alkaline accumulators, with 134 references.

3462
Brown, Stanley. DEVELOPMENTS IN THE FIELD OF BATTERIES. Radio & Electron. Comp., 2:831-835, illus., Nov. 1961.

Two main categories of batteries are briefly described - the secondary or storage batteries, and the primary batteries. Current trends in fuel cell utilization are also mentioned.

3463
Cohn, G. and Hauel, A.P. CATALYTIC DEPOLARIZATION OF PRIMARY BATTERIES. Engelhard Inds. Inc., Tech. Bull. 2:54-57, 1961.

Organic depolarizers were investigated which may replace the conventionally used MnO_2 in the Laclanche cell. For more detailed abstract, see Chem. Abs. 65:3258, Feb. 19, 1962.

3464
Cook Electric Co., Dayton, Ohio. ALKALINE BATTERY EVALUATION, by I.F. Luke, W.G. Ingling and W.W. Clark. 70p., Oct., 1961. (ASD TR 61-236) (Contract AF 33(616)-7529).

Objective of the evaluation was to establish battery test data for use in the design of the electrical system of future space vehicles and to determine the actual failure mechanism of all new battery systems under varying environmental and cycle-life conditions.

3465
Eagle-Picher Co., Joplin, Mo. DESIGN, DEVELOPMENT, QUALIFICATION AND TESTING OF BATTERY BA-487( )/U, Final Report, June 23, 1960 - June 30, 1961. 140p., June 30, 1961. (Contract DA 36-039-sc-85050).

The BA-487 ( )/U battery was developed for use in the Sergeant missile system. This battery weighs 55 lbs., has a nominal voltage on two identical sections of 29 volts and a capacity of approximately 1200 amp. min. per section. This program used design theories and hardware previously developed for batteries such as the BA-472/U, BA-485/U and BA-486/U. The 30-battery qualification testing proved this battery to be capable of meeting and exceeding the requirements called for in Specification SCL-6847B.

3466
Eagle-Picher Co., Chemicals and Metals Division, Joplin, Mo. RESEARCH ON AMMONIA BATTERY SYSTEM, by D.J. Doan, M.F. Chubb, et al. 5 issues, Oct. 1960, Jan., Apr., Jly., Oct. 1961. (Quart. Repts. 1 through 5) (Contract DA 36-039-sc-85396).

Research is reported which has for its objective the establishment of the feasibility of the liquid ammonia system in galvanic cells and the development of the use of this system in batteries.

3467
Eastman Kodak Co., Apparatus and Optical Division, Rochester, N.Y. HIGH ENERGY BATTERIES, Final Report, June 15, 1958 - June 14, 1961, by V.M. Bryant, J.M. Fruend and J.B. Schliff. 88p., Jly. 31, 1961. (Rept. EK/ARD ED-670) (Contract Nord-18249).

It was concluded that the feasibility of very high energy batteries has not yet been demonstrated as the result of an investigation based on the use of magnesium-sulfur couple in an electrolytic solution in liquid ammonia.

3468
Holechek, J.J. CHEMICAL HEATING FOR MISSILE BATTERIES. In Power Sources Conference. Proceedings, 15th, 1961, p.89-92, figs., Red Bank, N.J., PSC Publications Committee, 1961.

Some of the activation devices developed for general application to the zinc-silver oxide primary battery are indicated. Investigation, thus far, has furnished proof that chemical heat and heat exchanger devices are feasible.

3469
Lozier, G.S. NEW MATERIALS FOR PRIMARY BATTERIES. Inst. Radio Engrs. Trans. MIL-6:72-77, figs., Jan. 1962.

The selection of new anode-cathode combinations for primary cells is described on the basis of ampere-hour capacity, theoretical and operating potential, handling properites with respect to the design of primary batteries, and limitations placed on the selection of active components by unusual electrolyte requirements.

A magnesium/magnesium perchlorate/m-dinitrobenzene dry cell with an experimental capacity of 90 wh/lb and estimated maximum available capacity of 150 wh/lb is described. The basic relationships between the cathode potential of aromatic nitro compounds and the nature of substitution groups are illustrated. The development of high-capacity dry cells with a perchlorate electrolyte, a magnesium anode, and a cupric oxide or synthetic manganese dioxide cathode is described. The capacity of a magnesium/magnesium perchlorate/mercuric oxide cell on a 30-minute discharge rate with a voltage tolerance of ± 5 per cent is 50 wh/lb and 3.0 wh/cubic in.

3470
Mallory Battery Co., North Tarrytown, N.Y. TESTING AND EVALUATION OF PRIMARY ALKALINE CELLS AND BATTERIES, January 15, 1960 - March 1, 1961, by R.M. Goodman. 2 issues, Sept. 1960, Mar. 1961. (Semi-Annual Repts. 1 and 2) (Contract DA-36-039 SC-78320).

Objective of the contract is the testing and evaluation of primary alkaline cells of the zinc-alkaline-mercury system over a wide range of temperature, discharge rate and storage.

3471
National Carbon Co., Cleveland, Ohio. CONTINUOUS FEED PRIMARY BATTERY OF THE SODIUM AMALGAM/OXYGEN TYPE, by M.R. Hatfield and E.A. Schumacher. 7 issues, 1956 - 1958. (Quart. Tech. Repts. 1 through 6, and Terminal Tech. Rept.) (AD-117 309, AD-132 853, AD-133 579, AD-157 996, AD-157 995, AD-301 978).

Behavior of sodium amalgam anodes and carbon-oxygen cathodes were examined under a variety of operating conditions.

3472
Radio Corp. of America, Semiconductor and Materials Div., Somerville, N.J. HIGH CAPACITY MAGNESIUM BATTERIES, June 1 - November 30, 1961. 2 issues, Aug. 31, Nov. 31, 1961. (Repts. 5, 6) (Contract DA 36-039-sc-85340).

An analysis of the heat evolved from magnesium cells is presented. Emphasis is placed on performance o. mercuric oxide reserve cells at high discharge rates. Further development of $Mg/Mg(ClO_4)_2/HgO$ high-rate reserve cells is summarized.

Delayed action and impedance data are presented for $Mg/Mg(ClO_4)_2/MnO_2$ "A"-size cells made with AZ-21 magnesium alloy and compared with that of other alloys. Data are also included for peak voltages observed in switching from high-to-low discharge drains. Shelf data are summarized for manganese-dioxide and cupric-oxide cells stored for one year.

3473
Radio Corp. of America, Semiconductor and Materials Div., Somerville, N.J. ORGANIC DEPOLARIZED PRIMARY BATTERIES, by G.S. Lozier, J.B. Eisen, and R.J. Ryan. 27p., illus., Sept. 14, 1961. (Quart. Prog. Rept. 1) (Contract DA36-039-sc-87243) (AD-272 666).

A program was started to enlarge the scope of m-dinitrobenzene-C studies to determine the fundamental properties of the C affecting cell performance. The development of a practical Mg n-DNB cell is dependent upon gaining a thorough understanding of the function of carbon in the nitro-organic cathode. Also included will be a study to determine the mechanism of the nitro reduction reaction.

3474
Tarrin, M. ELECTRIC BATTERIES ACCORDING TO RECENT PATENTS. Rev. Gen. Elec., 69:441-460, Sept. 1960.

In French. This article follows on earlier reviews and examines recent French patents. The author indicates the impact of modern requirements for numerous electronic systems, such as missile controls, communication systems and recording systems. The patents reviewed reflect these requirements for improved dry-, primary, and miniature cells to meet various demands such as short-time high-current impulses and long steady current supplies. The use of magnesium to replace zinc and the introduction of new couples (copper and magnesium) in a chloride cell are noted. (Sci. Abs. 64B: 5126, 1961).

3475
Vic, R. PILES ELECTRIQUES. (ELECTRIC PRIMARY CELLS). Onde Elec. 41:209-219, Mar. 1961.

In French. Reviews the construction and operation of primary cells, with a detailed description of the widely used magnesium dioxide/zinc cell. The construction of its various types is given, with their performance and design considerations. Other primary cells used for special applications are each reviewed in turn, including mercury cells, air depolarized types using acid and alkaline electrolytes, copper-oxide cells, several new dry cells under development, firing cells, magnesium/copper-chloride types, and several kinds of fuel cells. (Sci. Abs. 64B:6173, Nov., 1961).

3476
Yardney Electric Corp., New York, N. Y. DESIGN AND CONSTRUCTION OF YARDNEY PRIMARY BATTERY BA-(X-R)/U, Final Report, January 1957 - September 1960. 23p., illus., Nov. 1960. (Contract DA36-039-sc-73157) (AD-252 250).

Design and performance data of silver-zinc primary battery BA(X-R)/U is presented. Description of the battery and variables used in the unit cell design and the results obtained are included. Performance results of complete batteries tested under various environmental conditions are also presented.

VII. ENERGY STORAGE

A. General Information

3477
Cameron, D. B. NEW BATTERIES, PROGRESS OR CONFUSION? Electron. World 66: 33-36, illus., Oct., 1961.

Description, characteristics, and applications of the new alkaline-manganese and sealed nickel-cadmium types.

3478
Eagle-Picher Co., Joplin, Mo. RESEARCH INVESTIGATIONS LEADING TO THE DEVELOPMENT AND EVALUATION OF A CADMIUM-SILVER OXIDE BATTERY HAVING A HERMETICALLY SEALED CONSTRUCTION, by J. Wilson. 2 issues, June, Sept. 1961. (Repts. 4, 5) (Contract DA36-039-sc-85370).

Various details are reported relative to fabrication, materials, and tests.

3479
Gulton Industries, Inc., Metuchen, N. J. INVESTIGATIONS LEADING TO THE DEVELOPMENT OF IMPROVED SEALED NICKEL-CADMIUM BATTERIES, by H. N. Seiger, R. C. Shair, etal. 2 issues, June 30, Sept. 30, 1961. (Quart. Prog. Repts. 4, 5) (Contract DA36-039-sc-85390).

Reports of progress and conclusions are given on ceramic seals, separators, uniformity, and stabilization of the positive electrodes.

3480
Shair, R. C., Rampel, G., and Kantner, E. HERMETICALLY-SEALED NICKEL-CADMIUM AND SILVER-CADMIUM STORAGE BATTERIES. Inst. Radio Engrs. Trans. MIL-6:67-71, illus., Jan., 1962.

The galvanic battery is the most highly developed means of storing electrical energy today. In satellite and space-vehicle applications where auxiliary electrical power is required for extended periods of time, it has been found that the most feasible power supply currently available consists of silicon solar cells used in conjunction with sealed nickel-cadmium storage batteries. They are capable of thousands of repeated cycles and have an energy output of about 12 watt-hours per pound. Sealed

silver-cadmium cells are of interest because of their higher output, 24-watt-hours per pound, but they are not as far developed, nor do they as yet have the cycle life of nickel-cadmium cells.

3481
Gulton Industries, Inc. Alkaline Battery Div., Metuchen, N.J.
NICKEL-CADMIUM BATTERIES, by G. Rampel and R. Dagnall. 51p., Jan. 1961. (WADD TR 61-34) (Contract AF 33(600)-41670) (AD-270 870).

Fundamental studies on electrode mechanisms have been treated theoretically and data is being collected to understand the basic processes occurring in a sealed nickel-cadmium cell. Improved techniques were developed to impregnate active material into electrodes so as to gain increased output. Studies were made of the parameters involved in assemblying sealed cells so as to achieve high overcharge capability without sacrificing capacity.

3482
Gulton Industries, Inc. Alkaline Battery Div., Metuchen, N.J.
SILVER-CADMIUM BATTERIES, by G. Rampel and R.C. Shair. 28p., June 1961. (WADD TR 61-131) (Contract AF 33(600)-42397) (AD-264 218).

Research and development are reported on a long life, reliable, high-watt-per-pound, sealed, silver-cadmium battery.

3483
Johns Hopkins University. Applied Physics Laboratory, Silver Spring, Md.
A COMPARISON OF SILVER-CADMIUM AND NICKEL-CADMIUM BATTERIES FOR USE ON THE TRANSIT SATELLITE, by W.E. Radford. 23p., Jan. 30, 1962. (CF-2970) (Contract NOrd-7386).

The replacement of Ni-Cd batteries with Ag-Cd batteries is reported to decrease the weight, while maintaining the capacity, of a given power system. This paper is the result of an investigation of this possibility. Areas investigated are: (1) the capability of a solar cell Ag-Cd cell system to limit overcharge current; (2) compatibility of solar cells and Ag-Cd cells in such a power system; (3) relationship between temperature of the secondary cells and their end of charge and discharge voltages for Ni-Cd and Ag-Cd cells; (4) relative weight and volume advantages in the use of Ag-Cd cells over Ni-Cd cells.

3484
Romanov, V.V. STRUCTURE OF THE CHARGED SILVER ELECTRODE IN THE ZINC-SILVER STORAGE BATTERY. Zhurn. Priklad. Khim. 33:2071-2078, 1960.

In Russian. Abs. in Chem. Abs. 55: 17294, 1961.

3485
Schulman, I.M. THERMAL DESIGN AND RECHARGING OF SATELLITE BATTERIES. Space/Aero. R & D Technical Handbook 4:G9-G11, 1961/1962.

The problems in designing an electric storage battery for a satellite are related. The heat generated in the battery, and the way in which the battery is recharged, are presented in graphic form. This information is an indication of how the design must be integrated with that of the overall electric power system. (Astron. Info. Survey 4:41, 159, Nov. 1961).

B. Chemical

3486
SOLAR ENERGY PROBLEMS. Chem. & Eng. News, 34:3250, Jly. 2, 1956.

Farrington Daniels of the University of Wisconsin points out promising areas of research in storing solar energy chemically, then releasing energy through fuel cells. Three storage methods are suggested.

VIII. ENERGY SOURCES

A. Chemical Fuels.

3487
Electro-Optical Systems, Inc., Pasadena, Calif.
CHEMICAL REACTIONS TO CONVERT SOLAR ENERGY INTO POWER SOURCES, by J.J. Rowlette. 44p., Sept. 1961. (ARL 60) (Contract AF 33(616)6546).

A theoretical examination given in this report indicates the possiblity of achieving conversion efficiences higher than those obtainable by any present device, although some very general outlines of an approach to the problem are apparent at this time.

3488
Levine, Sumner, et al. PHOTOCHEMICAL ASPECTS OF SOLAR ENERGY UTILIZATION. Solar En. 2:11-21, 1958.

The present outlook for a practical procedure for chemically converting solar energy is something short of optimistic. None of the known endothermic reactions, per se, approach the minimal criteria of a high quantum yield, a broad action spectra extending through the visible and large positive ΔF^{o}. The majority of the known reactions proceed at wavelengths below about 4000 A- a region which accounts for only 4 per cent of the incident solar energy. Clearly, the greatest need at this time is for photosensitizers which will extend the action spectra well into the visible portion of the solar spectra. Some small beginnings in this respect have been made with the cerous-ceric sensitized decomposition of water in the ultraviolet. The zinc oxide sensitized formation of hydrogen peroxide also proceeds in the ultraviolet. However, in this instance, other solidstate catalysts have been described which bring about hydrogen peroxide formation well into the visible. Unfortunately, the yields of H_2O_2 are very small. The possiblity of utilizing organic dyestuffs together with solid state catalysts may hold some promise, though this approach has not been pursued. The photodecomposition of nitrosyl chloride, on the other hand, proceeds well into the visible. The gaseous products can be removed from the system, thereby avoiding the photostationary state. Perhaps the major intrinsic shortcoming of this system is the small standard free energy change.

C. Nuclear

1. General Information

3489
Avco Corp., Research and Advanced Development Div., Wilmington, Mass. PRELIMINARY ENGINEERING ANALYSIS OF POWER SOURCES FOR SPACE VEHICLES, by E.F. Boose, H.K. McCard, and J.G. Lundholm, Jr. 72p., illus. Aug. 25, 1961. (Tech. Memo. RAD-TM-61-12) (Contract AF04(647)305) (AD-263 044).

A preliminary investigation has been made of 5 different power systems capable of continuously furnishing 10 kw of electrical power. The study was done in order to determine the pertinent system characteristics and to see which type of power system appeared most suitable for early use with an electrothermal propulsion system on a space vehicle. Of the systems considered, the study shows that at the present time, the nuclear turbine-alternator system is the best choice. If there was a question of reliability of the turbine-alternator unit, or if the orbital start-up problem is not satisfactorily solved, then the nuclear thermoelectric system would be the next choice with a 400-lb weight penalty over that of the nuclear turbine-alternator system.

3490
Budker, G.I. THERMONUCLEAR REACTIONS IN A SYSTEM WITH MAGNETIC STOPPERS AND THE PROBLEM OF DIRECT TRANSFORMATION OF THERMONUCLEAR ENERGY INTO ELECTRICAL ENERGY (PHYSICAL PRINCIPLES AND PRELIMINARY CALCULATIONS). In Akademii Nauk. SSSR. Institut of Controlled Thermonuclear Reactions, v.III, p.1-33, London, New York, Pergamon Press, 1959.

Translated from the Russian. The physical principles and preliminary calculations presented in the investigation concern the methods for realizing a thermonuclear reaction in a straight cylinder closed at the ends by magnetic "mirrors". A method is investigated for igniting the discharge in a high vacuum and for heating the plasma with the help of a magnetic piston. In addition to this, an examination is made of the question of direct transformation of nuclear energy into electrical energy.

3491
Connor, J.A., Jr. AEROSPACE NUCLEAR SAFETY. Aerospace Med. 31:797-806, 1960.

The basic principle used in aerospace programs is the conversion of nuclear heat to propulsive and/or electric power. Aerospace nuclear safety is discussed in relation to nuclear and flight technology and health considerations.

3492
Hendry, W.J. and Koshuba, W.J. NUCLEONICS IN FLIGHT. Metal Prog. 80:132, 134, 138-139, 142, 144, Aug. 1961.

A brief description is given of auxiliary power systems for space flight.

3493
Johnson, K. P. SECONDARY NUCLEAR POWER PLANTS. Space/Aero., 37:71-74, illus., Apr. 1962.

Reviews present state of the art and future systems for providing nuclear electric power for space vehicles. Emphasizes the need for higher radiator temperatues to make possible power units capable of delivering levels over 510 kw.

3494
POWER PACKAGE FOR THE MOON. Westinghouse Engr., 22:25, Jan. 1962.

A model of a nuclear thermoelectric power system designed for space applications is described.

3495
Ross, D. P., and others. A ONE-MEGAWATT NUCLEAR ELECTRICAL POWER PLANT FOR SPACE APPLICATIONS. In Ballistic Missile and Space Technology, v. II, p. 373-382, New York, Academic Press, 1960.

The nuclear potassium vapor power system presented offers attractive weight-to-power ratios and is based on design features permitting development within the next several years. Component design philosophy is such that in the event of a failure in a section of the power plant, a major portion of the power will remain deliverable. The four rotating machinery packages and the independent condenser-radiators make this possible. Considering the availability of future chemical boosters, the early development of a 1 Mw power conversion system would be of much value to the exploration and utilization of space by man. (Nuclear Sci. Abs., 15:8368, 1961).

3496
Shoupp, W. THERMOELECTRIC DIRECT CONVERSION IN NUCLEAR REACTORS. Nuclear En., 5:458-461, Oct., 1960.

Nuclear reactor, as prime example of passive (no moving parts) heat source, is examined for its attributes for power generation; future possibility of direct conversion of fission energy through thermoelectric and thermionic generation can be achieved for systems operating at high temperature, and depends on ability to develop high temperature structural and thermoelectric materials; nuclear reactor offers ideal source for magnetohydrodynamic and other direct conversion methods.

3497
SNAP: SYSTEMS FOR NUCLEAR AUXILIARY POWER. Mach. Design, 33:32, 34, June 22, 1961.

The key to exploration in deep space is electric power. Everything from vehicle lighting to propulsion will depend on electricity. The dramatically successful SNAP program provides a selection of power sources to meet any forseeable demand.

3498
Stambler, Irwin. THE ATOM AND SPACE. Space/Aero., 37:60-66, illus., Apr., 1962.

Current aerospace nuclear development programs are reported including the SNAP (systems for nuclear auxiliary power), SPUR (space power unit reactor), and STAR (space thermionic auxiliary reactor) projects.

3499
Teller, Edward. NUCLEAR POWER POTENTIAL FOR SPACE. In Bureau of Naval Weapons. Missiles and Rockets Symposium, April 1961. Proceedings, p. 15-17, Concord, Calif., U.S. Naval Ammunition Depot, Apr. 1961.

General talk on use of nuclear power with an indication of possibilities for use in space.

2. Isotopes

3500
AEC PLANS LAUNCH VEHICLE BUY TO STUDY NUCLEAR PROPULSION HAZARD. Aviat. Wk. and Space Tech. 75:30, Oct. 30, 1961.

Also mentioned at the International Symposium on Aerospace Nuclear Propulsion in Las Vegas, Nevada was a plan for a radioisotope thermoelectric generator using Curium 242 isotope as the heat source for electric power supply of the Surveyor unmanned, soft-landed lunar spacecraft.

3501
AUTO MIT ATOMBATTERIE. (AUTOMOBILE WITH NUCLEAR BATTERY). Physik. Bl. 18:18, Feb. 1962.

"Soviet scientists are reported to have

equipped automobiles with little ' nuclear batteries.' The automobiles supposedly can be driven for several years without recharging. The thermal energy developed by these reactors of the size of a pail is stated to be transformed directly into electric energy." Trans. of entire item.

3502
Barsch, Gerhard, Müller, Paul, and Euler, K.J. NUCLEAR BATTERY FOR THE TRANSFORMATION OF RADIOACTIVE RADIATION ENERGY INTO ELECTRICAL ENERGY. German patent 1,055,144 (To Accumulatoren-Fabrik Akt.-Ges), Apr.16, 1959. Abstract in Chem. Abs. 55:25308, 1961.

3503
Columbia University. Lamont Geological Observatory, Palisades, N.Y. TO STUDY AND MEASURE THE MOTION OF THE DEEP OCEAN FLOOR IN THE FREQUENCY RANGE OF SEISMIC WAVES, April 1 - October 30, 1961. 3p., Oct. 30, 1961. (Semi-annual Tech. Rept.) (Contract AF 19(604)-8357).

The expected delivery is reported of thermonuclear powered cesium batteries of long life, to be utilized in an ocean bottom seismograph system.

3504
Crompton, C.E. ISOTOPIC POWER. Indus. Res. 3:78-83, Oct., 1961.

The use of isotopic-powered generators for the TRANSIT and SNAP projects is discussed, and evaluation of radio-isotope-fueled power sources is presented, and future space applicaiions are outlined. (Astron. Info. Survey 4:40, 869, Oct. 1961).

3505
Greenfield, H.H. and Kittleson, R.E. SPACE-PROBE RADIOISOTOPE THERMOELECTRIC GENERATOR POWER SYSTEM DESIGN CONSIDERATIONS. Am. Nuclear Soc. Trans. 4:161-162, June 1961.

The design of a spaceprobe power system is considered using multiple SNAP III type thermoelectric generators.

3506
Harvey, D.G. and Carpenter, R.T. TRANSIT AND BEYOND. 11p., New York, Institute of Aerospace Sciences, Jan. 1962. (Paper 62-61).

A paper presented at the 30th IAS Meeting in New York, January 1962 discusses characteristics of a SNAP unit advantages and disadvantages of such a system, and the missions best suited to their application. The Transit SNAP unit is described, and the conceptual designs of the Surveyor and a communications satellite auxiliary power system are presented.

3507
ISOTOPE POWERED AUTOMATIC WEATHER STATION. Engr. 212:461-462, Sept. 15, 1961. Also in Engl. 192:368, Sept. 22, 1961.

Rugged meteorological instruments, mounted as integral parts of the station, will measure wind direction and speed, temperature, and barometric pressure. The readings go directly from the data processing system to the transmitter. The power source uses the isotope strontium 90, which can produce usable power for over ten years. (Instr. Abs. 16:7513, 1961).

3508
Libby, W.F. INDUSTRIAL USES OF ISOTOPES. In Annual Review of Nuclear Science, v.11, p.461-482, Palo Alto, Calif., Annual Reviews, Inc., 1961.

Isotopic power sources are discussed, p.474-475.

3509
Martin Co., Nuclear Division, Baltimore, Md. DATA TELEMETRY PACKAGE POWERED BY STRONTIUM-90 FUELED GENERATOR. Final Report. 206p., Sept. 1961. (Contract AT(30-1)-2519).

An automatic, nuclear powered, meteorological data transmitting radio station was designed and fabricated for unattended service at a remote Arctic location. Components and capabilities are described.

3510
Martin Co., Nuclear Division, Baltimore, Md. FINAL SAFETY ANALYSIS: TEN-WATT STRONTIUM-90 FUELED GENERATOR FOR AN UNATTENDED LIGHT BUOY, SNAP-7A. 51p., 1961. (Rept. P-2613) (Contract AT(30-3)-217).

The results are presented of a safety analysis of a prototype strontium-90 fueled generator. The fuel capsules produce 256.5 watts(t), from the decay energy, which is converted to 10 watts(e), with a 5 watt net

output from the batteries. The generator can be safely transported and operated with normal precautions afforded any structure containing a radioisotope. The shielding provided is adequate for protection against direct radiation exposure. The integrity of the system is maintained under most conceivable accident conditions.

3511
Martin Co., Nuclear Division, Baltimore, Md. FINAL SAFETY ANALYSIS: TEN-WATT STRONTIUM 90 FUELED GENERATOR FOR AN UNATTENDED METEOROLOGICAL STATION, SNAP-7C, by P.M. Brooks. 51p., 1961. (Rept. P-2614).

The analysis indicated that the generator can be safely transported and operated with the normal orecautions afforded any structure containing a radioisotope. The shielding provided for protection against direct radiation exposure is considered adequate. Integrity of the system is maintained under most conceivable accident conditions. The insolubility and chemical stability of the radio-strontium titanate is incidental as long as containment is maintained.

3512
Martin Co., Nuclear Division, Baltimore, Md. ISOTOPIC POWER SOURCES. A COMPENDIUM. PROPERTY AND PROCESSES REVIEW. 3v., June 1961. (MND-P-2581) (Contract AT(30-3)-217).

Nuclear, physical and chemical properties and separation processes have been emphasized in this 2063 references bibliography, in 3 parts. Isotopes covered are SP-90, Cs-137, Ce-144, Pm-147, Po-210, Ra-228, Ac-227, Th-228, U232, Np-237, Pu-238, Pu-239, Pu-241, Am-241, Cm-242, Cm-243 and Cm-244.

2513
Martin Co., Nuclear Division, Baltimore, Md. INSTRUCTION MANUAL SNAP-7C ELECTRIC GENERATION SYSTEM. 1/2 in. thick, Oct. 1, 1961. (MND-P-2640).

The system consists of a 10-watt thermoelectric generator fueled by Strontium 90, a biological shield, a DC to DC converter, and a nickel-cadmium battery. Heat from the decaying radioisotopes flows through the thermoelectric elements, causing generation of a low DC voltage. The DC to DC converter steps up the generator output voltage to charge the battery. The nickel-cadmium battery stores the electrical energy developed by the thermoelectric generator to supply the high rate loads demands of the weather station.

3514
Martin Co., Nuclear Division, Baltimore, Md. RADIOISOTOPE SEMICONDUCTOR AND THERMOELEMENT RESEARCH AND DEVELOPMENT, February 13-May 31, 1961, by J.B. Weddell. 66p., June 27, 1961. (Quart. Prog. Rept. 1) (Contract AT(30-1)-2698).

Progress is reported in the development of materials, composed principally of strontium titanate in which the decay energy of strontium-90 contained in the material is converted to electrical energy. The conversion is accomplished in part by the Seebeck effect, with the unevenly distributed strontium-90 serving as a heat source within the thermoelectric titanate material. Specimens of strontium titanate, containing additions of iron, molybdenum, tungsten, ferric nitrate, and ferric oxide-titanium oxide have been produced by sintering in hydrogen at temperatures between 1400 and 1475°C. The thermoelectric properties of these materials have been measured. Material composed of 58.6 at.% strontium titanate and 41.4 at.% iron powder has a thermoelectric figure of merit of 6.8×10^{-5} deg^{-1}C at a temperature of 900°C and has been selected as the basic material for further development. (Nuclear Sci. Abs. 16:4422, Feb. 28, 1962).

3515
Martin Co., Nuclear Division, Baltimore, Md. SNAP PROGRAMS. Task 5: THERMIONIC ISOTOPIC POWER SYSTEMS. 101p., 1960. (Quart. Prog. Rept. 6) (Contract AT(30-3)-217) (Rept. P-3014-II).

Suitable radioisotope fuels and heat source containment capsules are being designed for SNAP-type generators with land, sea and space applications.

3516
Martin Co., Nuclear Division, Baltimore, Md. SNAP PROGRAMS: Task 6: FUEL TECHNOLOGY DEVELOPMENT PROGRAM, April 1 - June 30, 1961. 62p., June 30, 1961. (Quart. Prog. Rept. 7) (Contract AT(30-3)-217).

Progress made in the development of isotope power sources for thermoelectric

and thermionic conversion to electrical energy is reported.

3517
Martin Co. Nuclear Division, Baltimore, Md. STRONTIUM 90 FUELED THERMO-ELECTRIC GENERATOR DEVELOPMENT. SNAP 7 PROGRAM, by J.J. Keenan and W.S. West. 2 issues, Jly., Oct. 1961. (Repts. P2483-3, -4) (Quart. Prog. Repts. 3, 4) (Contract AT(30-3)-217).

The SNAP-7 program is being conducted for the purpose of developing four radio-isotope-fueled thermoelectric power generation systems. An important phase of this program is the processing of strontium-90 into heating sources for these systems.

3518
Martin Co., Nuclear Division, Baltimore, Md. STRONTIUM 90 FUELED THERMOELEC-TRIC GENERATOR POWER SOURCE, FIVE WATT U.S. NAVY WEATHER STATION, Final Report. 1/2 in. thick, undated. (MND-P-2707).

A radioisotope fueled thermoelectric generator system has been developed to provide electric power for a five-watt remote weather station which will auto-matically broadcast local weather condi-tions at regular intervals from Little America V, Antarctica. The system was designed to operate in the environmental extremes of the Antarctic Continent without attendance or maintenance for periods of two years, and to have a useful life of 10 years.

The SNAP-7C consists of a thermoelectric generator, a dc-dc voltage converter, and a battery pack to serve as a reservoir for the storage of electrical energy.

3519
Martin Co., Nuclear Division, Baltimore, Md. STRONTIUM 90 FUELED THERMOELEC-TRIC GENERATOR POWER SOURCE FOR FIVE-WATT U.S. COAST GUARD LIGHT BUOY, Final Report. 103p., Feb. 2, 1962. (Rept. P-2720).

This final report describes the 10-watt Sr-90 thermoelectric generator, the dc-to-dc converter, batteries and the method of installation in the light buoy. Operation of the buoy lamp has been continuous since December 15, 1961.

3520
Miller, Barry. LUNAR RADIOISOTOPE GENERATOR DETAILED. Aviat. Wk., 75:85, 87, 91, Nov. 13, 1961.

A generator is described which is designed to provide up to 25 watts of electrical power for instruments and electronic gear on the Surveyor softlanded lunar vehicle. It employs fuel capsule containing a small amount of curium 242 as a heat source for two parallel banks of lead telluride thermo-couples. Advantages cited are: reliability, nocturnal power and insensitivity to lunar environment.

3521
Morse, J.G. and Harvey, D.G. NUCLEAR ENERGY IN SPACE--RADIOISOTOPE AUXILIARY POWER SYSTEMS. Aerospace Eng., 20:8-9, 58-62, figs., Nov. 1961.

This new, rugged, compact and reliable device (converting heat to electricity without moving parts) operates independently of solar transients and is adaptable to power needs in space.

3522
Morse, J.G. SNAP RADIOISOTOPIC POWER SYSTEMS. Inst. Radio Engrs. Trans. NS-9: 34-44, illus., Jan. 1962.

A summary is presented of SNAP radio-isotopic power supplies. Three SNAP generators have already reached the hardware stage and there is indication of their capability of fulfilling the demands of a variety of space missions.

3523
Moseley, H.G.J. THE ATTAINMENT OF HIGH POTENTIALS BY THE USE OF RADIUM. Roy. Soc. London. Proc., 88A:471-476, 1913.

Marks first construction of an isotopic converter.

3524
NUCLEAR GENERATOR CONVERTS HEAT DIRECTLY INTO ELECTRICAL POWER. Frank. Inst. J., 271:352, Apr. 1961.

Designated the NAP-100, the generator produces approximately 150 watts of elec-trical power and is designed for one year of continuous unattended operation. Interest centers on providing long-life power source for facilities such as small unmanned sur-face radio beacons and weather stations.

3525
NUCLEAR POWERED "BLINKING" FOR NEW NAVIGATION BUOY. ISA J. 9:54, Jan. 1962.

Power for the flashing light in the 7-ton, 26-ft. high buoy comes from a drum sized generator (SNAP 7-A) at its base. First to operate under water, the system is expected to be good for 10 years or more without refueling.

3526
Ohmart Corp., Cincinnati, Ohio.
STUDY AND DEVELOPMENT OF NUCLEAR BATTERIES. 6 issues, 1954. (Quart. Sci. Repts. 1, 4, 6, 7, 8, and Final) (Contract AF33(616)-172) (AD-20 491, AD-29 337, AD-47 919, AD-48 094, AD-51 362, AD-84 555).

Construction and fabrication details are reviewed and results of tests are reported.

3527
Soler, Kliment. ATOMIC BATTERIES. Pokroky Matem. Fyz. a Astron. 6:15-23, 1961.

In Russian. Transl. no. FTD-TT-61-72, by Air Force Systems Command, Wright-Patterson Air Force Base, Oct. 1961. (AD-266 754).

The basic principle of atomic batteries, their development, and types are discussed. Maximum performance was attained when a solar light (solar battery) was used instead of radioactive radiation for the excitation of battery emf. Solar batteries were successfully used in the third Soviet satellite. In the US a miniature atomic battery whose energy source is radioactive Pm-147 is discussed; its beta radiation falls on a P layer where it produces light flashes, the light energy is then transformed into electric energy. The battery has the dimensions of a pill. A radioisotope signal light manufactured in the US is also mentioned.

3528
Streb, A. J., Wilson, R. J. and Bustard, T. S.
NUCLEAR AUXILIARY POWER UNIT FOR LUNAR EXPLORATION. Inst. Radio Engrs. Trans. NS-9:85-90, Jan., 1962.

The radioisotope thermoelectric generator appears to be an ideal electrical power supply for the initial unmanned lunar exploratory vehicles. A typical system design was generated in this paper to meet requirements which may be postulated on the basis of desired lunar measurements and known equipment. An examination of the design reveals that all components which constitute the thermoelectric generator are within the capabilities of present day technology.

3529
Vichney, Nicolas. THE FIRST SATELLITE OPERATING ON NUCLEAR ENERGY. Nature(Paris) no. 3316:356-357, Aug. 1961.

The generator of the Transit satellite is designed to furnish 2.7 w. for 5 years by utilizing Pu^{238}.

3. Fission Reactors

3530
Texas Instruments, Inc., Dallas, Tex.
A STUDY OF THERMOELECTRIC DIRECT-CONVERSION NUCLEAR REACTORS, November 1, 1960 - October 31, 1961, by R. A. Chapman, W. R. Clendinning, et al. 161p., illus., Nov. 1961. (Summary Rept.) (Contract Nonr-3344(00)) (AD-267 442).

For light-water moderated reactors using thermoelectric direct-conversion nuclear fuel elements, this study has demonstrated that: (1) the reactor using PbTe can be made critical with less than 20% U^{235} enrichment; (2) a prompt negative temperature coefficient of reactivity must be present in the fuel to obtain safe operation; (3) a cylindrical UO_2-PbTe element will withstand operating thermal stresses if properly designed; (4) the element can be fabricated, but at considerable cost; (5) the thermal power density must be considerably reduced upon introduction of the thermoelectric between the fuel and coolant; and (6) the most promising thermal cycle is provided by natural circulation. These results do not rule out feasibility. At present efficiencies, however, the utility of this reactor concept must rest primarily on its ability to provide silent mobile power regardless of other performance characteristics.

3531
A 1000-KW NUCLEAR POWER PLANT FOR SPACE FLIGHT. Luftfahrttechnik, 6:374-377, Dec. 1960.

In German. This article describes a possible solution for nuclear heat sources in spacecraft. The design of a closed gas circuit of a nuclear reactor driving an

anhydrous alternating-current generator is given. (Astron. Info. Abs. 3:30, 337, 1961).

3532
General Instrument Corp., Newark, N.J. PHASE I REPORT OF DEVELOPMENT TECHNIQUES FOR POWER PRODUCTION FROM MIXED FISSION PRODUCTS, by D. Eaton. 120p., Feb. 18, 1961. (NYO-9699) (Contract AT(30-1)2605).

An investigation was made into the various processes for the fixation of mixed fission products as solids in order to determine the extent they could be utilized as heat sources for thermoelectric generators. Generators of up to ten watts can be designed and built with state-of-the-art thermoelectric materials and mixed fission products soon to be available from the Idaho Falls calcination pilot plant. Mixed fission products from other processes and plants to be "on stream" in this decade will be capable of fueling practical generators into the kilowatt range using thermoelectric materials available in the same time period. A program for the optimization of thermoelectric convertor design utilizing the diffuse heat from a mixed fission product source is described, derivation pertinent equations are presented and results of the study are discussed. Conceptual designs for thermoelectric generators utilizing diffuse fission product heat sources are described. Problem areas regarding the use of mixed fission products in conceptual thermoelectric conversion device designs are discussed, with particular emphasis being placed on underwater applications. With power densities of 0.0002 watts per cubic centimeter, available now, and increases by factors of 50 to 1000 likely within the near future, thermoelectric generators of 3 to 300 watts are within the realm of present day design and fabrication techniques. Higher power levels, up to kilowatts will be available with the inevitable increase in thermoelectric material efficiency. (Nuclear Sci. Abs. 16:5626, Mar. 15, 1962).

3533
Ridenour, L.N. and Nierenberg, W.A. MODERN PHYSICS FOR THE ENGINEER. 383p., illus., New York, McGraw-Hill, 1961.

Direct conversion, p. 325, briefly mentions the "intriguing" possibilities of utilizing fission reactors for energy conversion. An illustration depicts a large fission machine designed to produce electric current by means of elastic waves in an ionized gas.

4. Fusion

3535
Post, R.F. CONTROLLED FUSION RESEARCH - AN APPLICATION OF THE PHYSICS OF HIGH TEMPERATURE PLASMAS. In Levine, S.N. ed. Selected Papers on New Techniques for Energy Conversion, p. 418-444, New York, Dover Publications, Inc., 1961.

Some of the long-range implications and advantages of achieving the production of power from controlled fusion reactions between isotopes of hydrogen, helium, and lithium are set forth. The physical conditions which seemingly must be established to accomplish this are presented. Reprinted from IRE Proceedings 45:134-160, Feb. 1957.

3534
Herold, E.W. CONTROLLED THERMONUCLEAR FUSION-ITS MEANING TO THE RADIO AND ELECTRONIC ENGINEER. In Levine, S.N. ed. Selected Papers on New Techniques for Energy Conversion, p. 393-417, New York, Dover Publications, Inc., 1961.

Controlled thermonuclear fusion in plasma discharges offers hope of a revolutionary new energy source. Major containment and heating problems present obstacles, however, these may be overcome in the future. The radio and electronic engineer has an opportunity to make major contributions, perhaps even to shorten the time appreciably. Reprinted from RCA Review 19:162-186, June 1958.

3536
Post, R.F. FUSION POWER. In Levine, S.N. ed. Selected Papers on New Techniques for Energy Conversion, p. 33-44, illus., New York, Dover Publications, Inc., 1961.

If man can tame the reactions in which the nuclei of atoms are fused rather than split, he will have an almost limitless source of energy. The problem is now being attacked in laboratories all over the world. Reprinted from Sci. Am. 197:73-84, Dec. 1957.

D. Solar Collection and Concentration

3537
Aerospace Corp., El Segundo, Calif. THE REFLECTED RADIATION RECEIVED BY AN EARTH SATELLITE, by E. Levin. 21p., illus., May 8, 1961. (Rept. TDR-594(1560-01)TN-3) (Contract AF04(647) 594) (AD-260 902).

Satellite design problems involving temperature control, electrical power available from solar cells and possibly path perturbations of balloon-type satellites lead to consideration of solar radiant energy. This analysis examines in detail the relative contribution of radiation reflected from the earth and received by the satellite compared to the direct incident solar radiation. The principal component of the reflected radiation (on a spherical satellite) is in the radial direction. This component diminishes to about 10% of the magnitude of the direct radiation at an altitude of about one earth radius. Components other than in the radial direction may generally be neglected.

3538
Blanco, P. and Fontan, L. POWER RESOURCES OTHER THAN THOSE REGARDED AS BASIC. INVESTIGATION AND EFFECTIVE USE OF THESE. In World Power Conference, Sectional Meeting, Madrid, June 1960. 8p., (Section IIC, General Report).

A table of efficiencies of solar energy conversion is given, with values ranging from 1.5% to 5% for conversion to electrical energy, using flat-plate collectors, and from 40% to 70% for conversion to thermal energy, using concentrating collectors. (Sci. Abs. 64B:631, Nov., 1961).

3539
Daye, C. J. THE SUNFLOWER SYSTEM - SOLAR POWER FOR SPACE. Mech. Eng. 83:56-59, Dec. 1961.

The design, operation, turbine-alternator package and growth potential of the Sunflower I solar power converter system are explained in detail.

3540
Deris, Nese. NEW CHART FOR SOLAR COLLECTORS PINPOINTS OPTIMUM ANGLE OF INCLINATION. Air Cond. Heat. & Vent. 58:57-60, figs., Aug., 1961.

The optimum angle of inclination of a fixed flat solar collector can be found for any locality. The method is applied here only to 40° latitude, but similar calculations can be made for any other. (Battelle Tech. Rev., 10:1078, Nov./Dec. 1961.)

3541
Edwards, D. K. and others. SPECTRAL AND DIRECTIONAL THERMAL RADIATION CHARACTERISTICS OF SELECTIVE SURFACES FOR SOLAR COLLECTORS. Solar En., 6:1-8, Jan.-Mar. 1962.

Surface systems suitable for collectors of solar heat energy are examined. Spectral radiation characteristics of metallic substrates coated with semiconductor and antireflection layers are considered. Directional spectral reflectances of several surface coatings are presented and evaluated. Commercial chemical dip treatments of copper and steel are shown to give selective characteristics desirable for low temperature collectors such as solar water heaters.

3542
Eibling, J. A. WHERE IS SCIENCE TAKING US? Sat. Rev., 44:50-51, Nov. 4, 1961.

An engine that runs on sunlight is described in an updated and expanded version of a talk given at the 1961 Rome conference on New Sources of Energy. Basic concept of engine, developed at Battelle Memorial Institute, is to trap concentrated solar radiation directly within the engine. Two major uses are foreseen: (1) to power extraterrestrial space vehicles, and (2) to provide a cheap, sturdy, simple source of power for under developed countries.

3543
EOS PERFECTING METAL SPACE MIRRORS. Missiles & Rockets 9:36, Nov. 13, 1961.

Without describing the actual electrochemical process, this article discusses the status of research projects being conducted by Electro-Optical Systems, Inc., of Pasadena, California, on fabrication of lightweight metallic mirrors of astronomical quality for space power systems.

3544
EXPLOSIVES SHAPE SOLAR MIRROR. Iron Age 188:79, Nov. 2, 1961.

The design features of a solar collector for space vehicle application are given and the technique used in its construction is described.

3545
Goodyear Aircraft Corp., Akron, Ohio. SOLAR ORIENTING DEVICE FOR EXPANDABLE FLAT-PANEL ARRAY, by G.J. McKeel. 3 issues, Oct.1961, Jan., Apr.1962. (Quart. Prog. Repts. 1, 2, 3) (Contract DA 36-039-sc-88913).

Five approaches (both closed- and open-loop) to an orientation system for a flat-panel expandable solar array are considered in regard to ± 10-deg orientation accuracy, 30-day unattended operation, and reduced orientation system power drain during periods of insufficient solar radiation. The wedge-shaped orientation sensor is analyzed for sensitivity and operation and compared with others that appear suitable for this program.

3546
Lof, G.O.G., Fester, D.A., and Duffie, J.A. ENERGY BALANCES ON A PARABOLIC CYLINDER SOLAR COLLECTOR. Am. Soc. Mech. Engrs. Ser. J. Eng. for Power, 84:24-32, figs., Jan., 1962.

A technique for optimizing the design of focusing solar collectors was developed through a detailed study of the energy balances for a parabolic-cylindrical reflector with tubular receivers of three diameters. Experimental data for concentration ratios of 10 to 22.5 and surface temperatures of 88 to 353°F are presented. Receiver temperature, meteorological variables (including solar radiation), and distribution of reflected radiation in the focal zone of the reflector were measured and correlated so as to permit optimization of concentration ratio.

3547
Mann, A.E. and Dubey, Michael. DESIGN CONSIDERATIONS OF THE SOLAR SIMULATOR. In Power Sources Conference, Proceedings, 15th, 1961, p.111-119, figs., Red Bank, N.J., PSC Publications Committee, 1961.

The nature of solar radiation is discussed in connection with solar simulator design. Tests to be performed by the simulators will fall into three classifications: (1) thermal balance determination; (2) solar energy conversion measurement; (3) material degradation evaluation.

3548
Mazur, Paul. DETERMINATION OF FOCUSING PROPERTIES OF SOLAR COLLECTORS BY AN INTEGRAL FORMULA. Solar En., 6:23-26, Jan. - Mar. 1962.

An analytical procedure is derived for determining the distribution of energy at the focal plane of a mirror such as is used in a solar collector system. The method is a general one that permits any shape of emitting and reflecting surfaces, and is an analytical equivalent of the conventional ray-tracing procedure of geometrical optics. The advantage provided is that the calculation of intensity of collected radiation at a given point can be performed on a digital computer in less than 15 seconds whereas one man-week is required for graphical ray tracing.

3549
Oman, Henry. SOLAR MACHINES IN SPACE. Indus. Res., 3:62-69, Oct.1961.

Survey of recent research and technological advances in the conversion of solar energy to electric power. Several approaches to the design and construction of sunlight concentrators for space use are discussed, as are some promising concepts for energy-conversion plants. A description of newly developed silicon solar cells for terrestrial applications is included. (Intern. Aerospace Abs., 61:10240).

3550
Penrod, E.B. and Prasanna, K.V. DESIGN OF A FLAT-PLATE COLLECTOR FOR A SOLAR EARTH HEAT PUMP. Solar En., 6:9-22, Jan.-Mar.1962.

In this paper a flat-plate collector is designed for a solar earth heat pump in which excess solar energy is stored at irregular intervals in the soil surrounding the ground coil. The method developed may be used in designing flat-plate collectors for any application.

3551
Sanborn, D.S. ALUMINUM FOIL SKINS BENEFIT 'WAY OUT' MIRROR. West. Metalworking 10:43-44, Nov.1961.

Stretch forming and resistance welding procedures used in fabrication of 3003 Al

alloy foil blades for solar space mirrors. (ASM Rev. Metal Lit. 19:15, Jan. 1962).

3552
Sanborn, D. S. THE DEVELOPMENT OF DEPLOYABLE SOLAR CONCENTRATORS FOR SPACE POWER. Preprint 425D of paper given at Soc. Automotive Engrs. National Aero. & Space Eng. & Mfg. meeting, Los Angeles, Calif., October 9-13, 1961.

Description of a foldable, parabolic, 10-ft, solar concentrator having an overall weight of less than 0.4 lb/ft^2. Such a system meets the presently contemplated performance requirements for efficient operation in conjuction with thermoelectric or Rankine-cycle turbine-alternator system. (Intern. Aerospace Abs. 61:10241).

3553
Sanborn, D. S. FOLDING MIRROR FOCUSES SUN FOR SPACE POWER. Soc. Automotive Engrs. J., 30:74-75, Jan., 1962.

Paper 425D. Large-scale, deployable solar concentrators for space power, weighing less than 0.4 lb per sq. ft, can be built using newly developed techniques. A novel deployment system allows the concentrator to be stowed in a cylindrical package having a diameter less than one-fourth and a length less than one-half the diameter of the extended concentrator.

3554
Shoemaker, M. J. NOTES ON A SOLAR COLLECTOR WITH UNIQUE AIR PERMEABLE MEDIA. Solar En., 5:138-141, illus., Oct./Dec. 1961.

Tests on plate heat collectors reveal that they are highly efficient in transferring heat and thus in increasing the temperature of a stream of air provided that the space between the cover and the bottom of the collector is filled with slit-and-expanded aluminum foil blackened on the one side, which is turned toward the sun. The air stream traverses the collector parallel to the general plane of the foil layers. The high radiant-energy exchange should reduce the cost of heat collectors and hasten wider utilization of solar heat.

3555
Stephens, C. W. and Haire, A. M. INTERNAL DESIGN CONSIDERATION FOR CAVITY-TYPE SOLAR ABSORBERS. Am. Rocket Soc. J., 31:896-901, Jly. 1961.

The effects of geometry and internal surface reflectivity on the performance of a cavity-type absorber used in solar power systems are discussed. By defining an average "view factor" of the cavity opening as seen by the cavity interior surface, it is possible to evaluate quantitatively the performance of a cavity operating at elevated temperatures. Only minor performance variations between the several cavity shapes considered existed, and it was found possible to approximate closely the ideal blackbody cavity absorber efficiency with real cavities of reasonable size. The analysis demonstrates that high performance cavities are attainable with internal surface reflectances on the order of 0.6 to 0.7. For these values, differences in heat absorption rate throughout the cavity may be minimized with the consequent reduction of the problem of internal "hot spots."

Also issued as ARS Preprint 1178-60, May 1960.

3556
Trombe, Felix, et al. CONCENTRATION D'ENERGIE SOLAIRE POUR LA REALISATION DE TRES HAUTES TEMPERATURES. (CONCENTRATION OF SOLAR ENERGY FOR THE USE OF VERY HIGH TEMPERATURES). Ann. Chim., 2:385-419, 1947.

In French. Complete history is given of the various attempts to utilize solar radiation; modern solar accumulators are described. Bibliography.

3557
Veynberg, V. B. OPTIKA V USTANOVKAKH DLYA ISPOL'ZOVENIYA SOLNECHNOY ENERGII. (OPTICS IN INSTALLATIONS FOR THE UTILIZATION OF SOLAR ENERGY). 185p., Moscow, State Publishing Office for the Defense Industry (Oborongiz), 1959.

In Russian. Trans. H-4787 by U.S. Dept. of the Army. Office of the Asst. Chief of Staff for Intelligence, Washington, D.C.

Although the problems of creating powerful solar photoelectrical, photochemical and thermoelectrical units are not touched upon in this book, it is stated that the problems of solar energy availability, sun-ray concentration, and other topics discussed will be of great value for their solution.

3558
"WAY OUT" MIRROR. Ryan Rept. 22:7-9, Aug. 1961.

Description of a solar reflector being developed by Ryan Aerospace Division for space power applications. A quarter-scale mirror model, which is a 10-ft-diam metal paraboloid consisting of 36 blade sectors, is described. Designed to remain folded during boost and to deploy automatically when the orbit is established, the mirror will concentrate the sun's rays into the power unit for engine operation. (Intern. Aerospace Abs. 61-9236).

IX. REGULATION AND CONTROL

3559
General Electric Co., West Lynn, Mass. VOLTAGE REGULATION AND POWER STABILITY IN UNCONVENTIONAL ELECTRICAL GENERATOR SYSTEMS. 3 issues, Dec. 1960, June, Sept. 1961. (Quart. Tech. Prog. Repts. 2, 4, 5) (Contract NOw 60-0824-c) (AD-254 324L, AD-265 158, AD-266 028).

Test data on the internal impedance characteristics of a fuel cell are presented. The feasibility of using a control grid for the voltage control of a fuel cell is discussed and illustrated with test data. Steady-state characteristics of a vapor thermionic converter are included. Applicable dc-dc and dc-ac circuits using silicon controlled rectifiers and power transistors are discussed. A qualitative evaluation of these circuits for use with unconventional power sources is included. The results of a survey of available silicon controlled rectifiers and power transistors are presented. A tentative study approach for evaluating the system (power source plus voltage converter) is given.

3560
Naval Research Laboratory, Washington, D.C. TUNNEL DIODE STATIC INVERTER, by J.M. Marzolf. 8p., illus., Oct. 25, 1961. (Interim Report) (Rept. 5706) (AD-268 835).

A simple static inverter circuit of two tunnel diodes and a transformer wound on a square loop magnetic core is described. Its characteristics make it particularly applicable for use with the new low-voltage, high-current unconventional dc power sources such as thermoelectric, thermionic, and fuel cell generators. In operation, the tunnel diode static inverter is relatively small with no short-circuit protection needed. The output is a high-quality ac square wave at any desired design voltage. The power output is limited only by the current capabilities of the tunnel diode. The high quality of the square wave output may recommend the use of this device as a low-frequency square-wave signal generator.

3561
NAVY STATIC INVERTER USES TUNNEL DIODES. Electron. Design 9:28-31, Nov. 22, 1961.

Static inverter consisting of two tunnel diodes and a square-loop magnetic-core transformer has provided square waves from low-voltage, high-current dc inputs reliably over reasonably wide ambient conditions. The inverter is intended for use with such power sources as thermoelectric, thermionic, and fuel-cell generators. (Battelle Tech. Rev. 11:61a, Feb. 1962).

AUTHOR INDEX

DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS. Compiled in the Library Branch, Technical Information Division, U.S. Naval Research Laboratory. 121 pages. December 1962.

A collection of references from various sources covering the current literature on thermoelectricity, thermionic emission, photoelectric processes, magnetohydrodynamics, electrochemical processes, energy storage, and energy sources.

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